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[*Authors alone are responsible for all opinions expressed in their Communications.*]

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THE

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THE ROYAL DUBLIN SOCIETY.

No. 1.

DISSEMINATION OF POTATO VIRUSES X AND F BY LEAF CONTACT.

By J. B. LOUGHNANE and PAUL A. MURPHY,

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[Read February 22. Published separately May 31, 1938.]

In the season of 1936 an experiment was carried out in the field to test the possibility that virus X might spread by contact of the foliage of healthy potato plants with that of plants containing this virus. Two plots were laid down at a distance of six feet from each other. In one of them, consisting of seven adjacent drills, twenty-four healthy half-tubers were grown alternating with tubers containing the X virus at a distance of ten inches from each other. In the other plot, the other twenty-four half-tubers were grown alternating with similar diseased tubers at a distance of four feet apart, every alternate drill being left vacant, with the result that there was no danger of foliage contact between the plants. All the healthy plants in both plots were shown to be free from virus X at the beginning of the experiment by inoculating each to 3 plants of *Datura Stramonium* before there was danger of contact. Towards the end of the growing season, the originally healthy plants were again tested for the presence of virus X by inoculating each to 2 plants of *Datura*. The result of this test was that eleven out of the original twenty-four healthy plants in the contact plot contracted virus X, while all the originally healthy plants in the no-contact plot were still X-free.

This result established the fact that transmission of the virus to potatoes was brought about by growing the plants in close proximity, but the means by which this took place, whether by contact of any part of the plants, or by insects, the transfer of which might be facilitated by proximity, was not determined.

In view of the occasional spread of simple mosaic (virus X), amongst other diseases, in pathological glasshouses in the absence of greenfly and other aerial insects, and its apparent rapid spread in the superlatively good seed-potato district of North Donegal, in which aphid-borne viruses are at a minimum, opinion had begun to move towards the view that insects might not be implicated in its spread. Cases of the spread of virus X from and to potato plants in houses are probably known to all potato virus workers, but no attention has been devoted to the source or method of infection. Potato plants are looked upon as notoriously difficult to infect by means of extracted sap without using special methods, such as carborundum, but there have been indications for some time that this difficulty does not exist in nature. A striking case occurred at Glasnevin in 1934/35. A potato plant of the variety Monocraat No. 4.364 containing a then unknown virus, which was afterwards identified as virus F (15, 3), was used as a source, in order to study the reactions of this virus in 1934, and was kept growing throughout the season in various positions on the benches, usually at the back, wherever room could be found. The work was continued in 1935 with a plant grown from a tuber of 4.364, but different reactions were at once obtained. As is shown later (p. 8), Monocraat No. 4.364 had become infected in 1934 with Up-to-Date streak caused by virus B (which is looked upon as a very intractable disease to transmit), as was clear from the fact that another portion of the same original stock which was not descended from 4.364 continued to give the original reactions.

For these reasons the idea was entertained that the spread might take place more easily by gentle contact of the leaves than had been supposed, and that the disease might be contagious in the strict sense, and might be spread in the field by a similar means. An experiment was, therefore, planned for 1937 to endeavour to answer the questions:—(1) Can simple mosaic spread from potato plant to potato plant in the absence of aphids and all known aerial insects, and under circumstances excluding transmission below ground? (2) Can its spread be stopped by preventing contact of the leaves, while allowing free access of insects above and below ground, and maintaining the usual spacing and root contact between the plants?

A preliminary account of the work so far as it relates to virus X has already appeared (12). The various viruses dealt with are designated as follows in Smith's system of nomenclature (25):—*Solanum virus 1* (*virus X*); *Solanum virus 8* (*virus F*); *Solanum virus 4* (*virus B*).

Experimental.

First Experiment.

The first experiment consisted of four parts, one (A) being carried out in an insect-proof glasshouse along with its control (B), and another (C) along with its control (D) in an open field. These took the form of inter-planting

tuber-portions free from virus X under different conditions between tubers containing this virus. In order to make all the material uniform each X-free tuber was divided according to its size into four quarters or two halves, one portion of each quartered tuber being used in each of the four parts, A, B, C, D, of the experiment (see upper part of Table 1), and one portion of each halved tuber being used in parts A and B alone (lower part of Table 1). This precaution was necessary, so as to ensure that all the presumed X-free material was uniform, and that it was all equally capable of contracting the infection (18).

The two lots of plants A and B under glass each consisted of 27 plants, and were grown in pots in ordinary unsterilised potting soil in the same compartment of an insect-proof glasshouse, separated only by a passage 3 feet wide. Fourteen of the plants in lot A were each grown in the same pot as a diseased plant, and the remainder (13) in separate pots about 1½ inches apart, as shown on the plan. The haulms in lot A were allowed to touch, which they did freely, as the plants were large and closely spaced, and in order to increase contact between the leaves an oscillating electric fan was allowed to play on the plants from a distance of 3 feet from the front row for a period of about 9 hours per week. The fan produced a current of 6 miles per hour (equivalent to nearly 3 m. per sec.) at a distance of 3 feet, which did not mark or injure the leaves. Lot B was treated similarly in every respect, except that no fan was used, and the aerial portions were effectively kept from touching by enclosing the haulms of each initially diseased plant in a cylinder of ½ inch mesh wire netting, which was open at the top. In this case 16 of the initially healthy plants were in the same pot as a diseased plant, and 11 in separate ones. Both in lot A and B a cane was on several occasions during the season driven into the soil of the pots containing two plants so as wound the roots.

Lot C, consisting of 14 plants, was grown in the field in three drills side by side, with the healthy plants and those containing virus X alternating in the same drill at a distance of one foot from each other. The diseased plants were grown inside double cages made of two concentric cylinders of ½ inch wire netting placed one inside the other, with an annular space of about one inch between them, and open at the top. Furthermore, all the plants in one drill, both healthy and diseased, were planted in nine inch flower pots sunk in the ground, in order to see if diminished root contact would have any effect on the spread of disease.

Lot D, also consisting of 14 plants, was grown in three other drills side by side, separated by an open space of 4 feet from lot C, and under identical conditions in all respects, except that there were no wire cages, and the foliage was allowed to touch freely. This arrangement was adopted so as preserve the usual spacing and root contact, without making insect access more difficult above or below ground. All cultivation in the field plots was done by hand.

The plants serving as sources of disease in lots A and B corresponded. Fourteen of these belonged to the varieties of President or Arran Victory, of which 9 contained virus X alone and 5 contained X + F, while one plant of

Up-to-Date (two in the case of lot B) contained X + B. It was desired in particular to find if virus F spread by leaf contact, as the only transmission known was by means of *Myzus persicae* in the presence of virus A (3), and it was concluded that there must be another mode of transmission in Nature, since the viruses generally occur separately. The sources of disease in lots C and D also corresponded, and all contained virus X; but although virus F was also included equally in both lots, heavy blight infection on the tubers prevented a satisfactory diagnosis of infection with this virus, which is recognised by the development of tuber necrosis in storage (11, 3).

A plan of the first experiment is shown in the figure, and the results are shown in Table 1. Notes were made on the appearance of the potato plants, but reliance was placed on infections from the potato leaves made on *Datura Stramonium.* As seen by the production of symptoms in *Datura,* 8 out of 27 potato plants in lot A became infected when the leaves were in contact with the diseased sources and the fan played on them. These included some plants of each of the three varieties represented, namely, 5 out of 14 President, 1 out of 9 Champion, and 2 out of 4 Arran Banner. Planting took place on March 9th, and the plants developed rapidly afterwards, as is usual under glass, but no infection was found to be present until July 2nd, although it may possibly have begun sooner in two cases, as the test on June 15th was not complete. The leaves were in general contact long before that date, and it is unknown whether older plants are more susceptible or whether the result is due to the increasing number of chances of contact following the passage of time. The absence of initial X infection is shown by the absence of symptoms in all plants of lot A in the first two tests in April and May, and the complete absence of symptoms in all plants of lot B throughout the experiment.

It is clear from the figure and table that the infection did not take place below ground, for none of the 16 healthy plants in lot B which were in the same pot as a diseased one contracted virus X, and of those which developed it in lot A, 5 were in the same pot as a diseased plant, but 3 were in separate ones. The determining factor evidently was contact of the haulms and not of the roots, for where the haulms were separated, even though the roots were growing intermingled in the same pot, no infection took place.

This conclusion is confirmed by the results in the field. The potatoes were planted in the last week of April, and were dug on October 6th, 1937. The amount of infection contracted was approximately one-half of that in the house, namely, 2 plants in 14 in lot C where the haulms were in contact, and 0 in 14 in lot D where the foliage was kept from touching by wire cylinders. The plants stood just as close to each other in both cases, and there must have been the same root contact, but this had no influence on infection. The same conclusion may be drawn from the fact that one of the two plants which became infected in lot C was growing in a flower-pot, as were the adjacent diseased plants, a fact which reduced root contact. It might perhaps have been argued in the case of plants growing in the same pot in a glasshouse that some soil

insect or other agency necessary for transmission was absent, but the failure of transmission to take place as a result of root contact in the field cannot easily be attributed to such a want. The nature of the material used to separate the haulms, namely, cylinders of ½ inch mesh wire netting open at the top, was such as to allow free access of all aerial insects, and its effect, therefore, was simply that of keeping the leaves from touching.

Proportionately about twice as many plants contracted virus X in the glasshouse as in the field, a difference which appears to be significant. The reason for this is uncertain, and it may be because of the influence of the fan in increasing leaf contact, although the leaves were in contact in the field over a longer period, which included both early and late summer, and were, as usual,

TABLE 1.—DEVELOPMENT OF X-INFECTION IN POTATO PLANTS IN GLASSHOUSE AND FIELD AS A RESULT OF LEAF CONTACT. FIRST EXPERIMENT.

House—Planted March 9, dug August 16, 1937.
Field—Planted April 27, dug October 6, 1937.

Variety.	Tuber fraction used.	No. of plants.	Number of originally healthy plants which developed X-infection.									
			A Glass-house Haulms in contact. Fan.					B Glass-house Haulms separated. No Fan.		C Field Haulms in contact.		D Field Haulms separated.
			5/4/'37	10/5/'37	15/6/'37	2/7/'37	3/8/'37	12/7/'37	4/8/'37	4/8/'37	6/10/'37	4/8/'37	6/10/'37
President . .	Quarters.	9	0	0	0	1	2	0	0	0	1	0	0
Champion . .	„	3	0	0	0	1	1	0	0	0	1	0	0
Arran Banner .	„	2	0	0	0	1	1	0	0	0	0	0	0
President . .	Halves	5	0	0	0	1	3	0	0	—	—	—	—
Champion . .	„	6	0	0	0	0	0	0	0	—	—	—	—
Arran Banner .	„	2	0	0	0	0	1	0	0	—	—	—	—
Totals . .	. .	27	0	0	0	4	8	0	0	0	2	0	0

subjected to much wind. It is possible that the type of growth produced in the hotter and drier air of the house facilitates infection, and in this connection it may be remarked that virus X is more abundant in the warmer, drier, and

less windy climate of the United States than in the cold, wet, and windy climate of Ireland. Köhler (10) found more spread of virus X at mid-summer than in autumn, but it is not known to what extent these plants were in contact with sources of X.

The two parts of the experiment, therefore, provide answers to the questions formulated at the beginning of the work. The house experiment proves, in the first place, that simple mosaic spreads freely in the absence of all known aerial insects, and in circumstances excluding transmission below ground. Both experiments show that its spread can be stopped by preventing leaf contact, and the field experiment in particular shows that the stoppage is still effective although there is free access of insects above and below ground. The conclusion is clear that the wire prevented infection by preventing leaf contact, and not by excluding aerial insects. It is clear from both experiments also that there is no transmission by root contact.

Second Experiment.

On the conclusion of the first experiment in the house, another planting was made at once on August 25th in order to assess the relative importance of leaf contact alone, and leaf contact with air currents. Sixteen X-free tubers were divided into three parts, one part of each being represented in E, F, and G, below, all of which were planted in separate pots in two compartments of an insect-proof glasshouse under the following conditions:—

Lot E, derived from 16 tuber-thirds, was grown in two lines on each side of 8 plants of President or Arran Victory, 4 containing virus X alone, and 4 containing viruses X and F in combination, with a distance of approximately 2 inches between the pots. The foliage of the diseased and healthy plants eventually came into contact as they grew, and an oscillating electric fan played on them, as before, for about 9 hours per week.

Lot F, which corresponded exactly, was grown in the next compartment in two lines on each side of similar diseased sources, and at the same distance from them, again with the foliage in contact, but without a fan.

Lot G, consisting of the 16 remaining thirds, was grown in two lines on each side of corresponding diseased sources, and at the same distance from them, but in order to prevent contact of the foliage all the plants, both healthy and diseased, were enclosed in cylinders of ½ inch mesh wire netting open at the top. This lot served as a control on the other two, and one-half of it was grown in the same compartment as lot E and the other half in the same as lot F, but on the other side of the passage in both cases.

The tubers were planted on August 25th, and the foliage of the initially X-free plants was tested for virus X by inoculation to *Datura Stramonium* at intervals, with the results shown in Table 2.

TABLE 2.—RATE AND TIME OF DEVELOPMENT OF X-INFECTION IN POTATO PLANTS. SECOND EXPERIMENT IN HOUSE.

Planted August 25, 1937.

Date.	Size of plants and amount of leaf contact in lots E and F.	No. of Plants.	Number of originally healthy plants which developed X-infection.		
			E Leaf contact. Fan.	F Leaf contact. No Fan.	G No contact. No Fan.
Sept. 3 . .	Plants small, leaves not yet in contact.	16	0	0	0
Sept. 14 . .	Plants medium size. Contact of leaves beginning.	16	0	—	—
Sept. 27/28 . .	Plants large. Good contact of leaves.	16	0	0	0
Oct. 8/9 . .	do. do.	16	4	0	0
Oct. 28 to Nov. 2	do. do.	16	4	1	0
	Totals . . .	16	4	1	0

The four potato plants which became infected in lot E showed mosaic symptoms, and it is remarkable that all of them were either suspect or showed a definite though partial mottle on September 27th, although they did not infect *Datura* on that day. It is clear that the potatoes did not become infected until leaf contact was established, and the process probably began soon afterwards. The effect of the fan was the same as before, for it not only increased the amount of infection, but advanced the date on which it took place. The only potato plant which contracted virus X in lot F showed no symptoms. There was no infection in either house where the haulms were not in contact. The distribution of X infection among the varieties was as follows in lot E: President 1/3 infected, Irish Chieftain 1/4 infected, Champion 2/9 infected. The single plant infected in lot F was Irish Chieftain (1/4 infected).

SPREAD OF VIRUS F BY LEAF CONTACT.

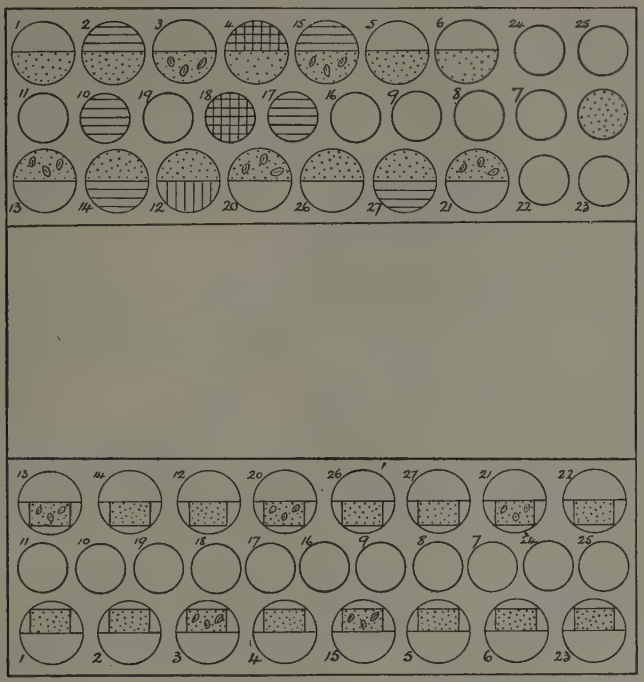
As already stated, virus F was included in some of the sources in all the experiments, and the fact was established in both the tests in the glass-house that it spread by leaf contact under the same conditions as virus X, but to a less extent. All the plants which were exposed to infection were free from virus F to begin with, and its presence was subsequently established by the development of necrosis in the tubers of President and Champion. This is an invariable symptom in these varieties, and it generally sets in during storage, although it may be visible at digging time (3).

Three plants in 18 contracted virus F in lot A of the first experiment in the varieties President and Champion, there being 5 other plants which were not in contact with a source of this virus. The proportions in President were 2 out of 12, and in Champion 1 out of 6. As may be seen from Fig. 1, the plants which contracted the infection stood next to a source of F, but it is remarkable that there was no case of transfer of the virus between two plants in the same pot. Evidently there is no infection through the roots. It may be that plants which stand some distance apart, so that their outer leaves rub together in the wind, are in a better position to infect each other than those closer together. No infection occurred except where it was reasonably certain from the position of the plants that leaf contact must have occurred, and there was no evidence of a distant transfer. It will be noted that, although the sources in this case contained viruses X and F, the latter was sometimes transmitted alone, as to plant No. 12, although this plant was susceptible to both viruses, and it is clear that viruses may be separated in Nature following mechanical infection. There is no present evidence that F is more infectious than X, and the result probably indicates an uneven distribution of the two viruses in the source, and infection from and to a single broken cell. No virus F (or any other infection) was contracted by lot B of the first experiment in which the haulms were separated. No data on the spread of F could be taken from lots C and D in the field.

In the second experiment, a single plant alone contracted virus F in lot E, where 4 plants of Champion, 2 of Irish Chieftain, and 2 of President were in foliage contact with a source of F. The diseased plant was a President. There was no spread of the virus in lot F (haulms in contact, without fan), or in lot G where the haulms were separated.

Accidental Transmission of Up-to-Date Streak (X + B) in Insect-proof Glasshouse.

It was not possible to obtain any data on the spread of Up-to-Date streak in the present experiment, but the accidental transfer of this disease, generally referred to the combination X + B, in an aphid-proof house under the same conditions as virus X has been referred to in the introduction. As this case is fully authenticated, the following particulars may be given of the stock of the Dutch variety Monocraat involved, which was grown throughout in an insect-proof house in the course of a comparison of Irish and Dutch potato viruses (15). In 1933 and 1934 it was proved free from X and B by repeated grafts on President, British Queen, Arran Crest, and Epicure, and by inoculation to tobacco, *Datura* and *Nicandra*. In 1935 part of the same stock (No. 4.364) gave the following reactions:—When grafted direct on potato it produced top necrosis on Epicure (as X does) and also on Arran Victory, Kerr's Pink, Golden Wonder, and Irish Chieftain; and mosaic or no symptoms on Arran Banner, Duke of York, and Great Scot; all of which are characteristic of X + B. When



1. Originally healthy plant in separate pot, which contracted no infection.
2. Originally healthy plants in the same pot as diseased sources, which contracted no infection.
3. Sources of virus X in the same pot as a healthy plant or in a separate pot.
4. Sources of virus X and F, all in the same pot as a healthy plant.
5. Sources of virus X and of X + F, with the haulms enclosed in wire netting cylinders. (All in the same pot as a healthy plant.)
6. Originally healthy plants which contracted virus X.
7. Originally healthy plants which contracted virus F.
8. Originally healthy plants which contracted X + F.

FIG. 1.—Diagram representing lots A and B of first experiment showing arrangement of plants in insect-proof house and number which contracted virus X.

sap-inoculated to *Datura* it produced mottle characteristic of X, but grafts of this *Datura* to potato showed that B was present as well, for they produced top necrosis on Epicure (X); and also top necrosis on President, Arran Victory, British Queen, Golden Wonder, and Irish Chieftain, and no symptoms on Arran Banner and Duke of York, all of which are the characteristics of X + B. The remainder of the Monocraat stock (all derived originally from the same single tuber in 1933) remained free from both X and B in 1935, and showed only virus F, as in the preceding years.

There can be no doubt of the transfer of Up-to-Date streak in this case, which constitutes the first record of natural spread and infectivity of the disease (26). Although it is a single instance, the event must probably be referred to leaf contact, in the absence of other known means, as in the case of virus X, in spite of the fact that the disease has been so transmitted artificially to potato only with difficulty (2), or not at all (1). Viruses X and B have much in common, and appear to spread under the same conditions in potato crops in Donegal (4). It is remarkable how closely they are associated, for if streak in Up-to-Date is caused by the combination of B and X, as appears to be the case (6, 1), the combination is a very stable one. B has never been found alone, while X has been found alone even in varieties which are almost permeated by B; and in all the cases now being discussed when B appears for the first time in new plants or crops it is always along with X. If it is a combination, therefore, the constituents are apparently differently and more uniformly distributed in the tissues than a combination like X and F, so that they do not easily separate.

Discussion.

The mode of transmission of simple mosaic has always been in dispute. It is not necessary to review all the work on the subject, because most of it has been negative, and the few positive results have not been generally accepted. The situation was summed up by Smith (24) in 1933 as follows: the virus "is not aphis-transmitted and the insect vectors are not known." More recently the same author (25) states that, although none of the common sap-sucking fauna of the potato plant is able to act as a vector, he appeared to have 5 positive infections out of 100 with species of thrips. The observation that varieties like Epicure, King Edward, and Great Scot, which have few flowers, are less attractive to thrips and show little mosaic in consequence, is now more simply explained since it is known that simple mosaic is never found in the first two varieties which are intolerant of it, and that it is carried by the third. Whatever agency is responsible in Nature, it is more efficient than any experimental technique which has been used up to the present.

It is probable that all virus workers who handle X-free potato plants have had cases of the accidental transmission of virus X in so-called insect-proof glass-houses, but no data are available. These houses are only free from the

larger sap-sucking and other aerial fauna, and do not necessarily exclude other forms of animal life, especially in the soil. Such cases of transmission are probably not so infrequent, especially where large numbers of potato plants are handled. There is nothing unusual in this, in view of the precautions necessary with tobacco and *Datura,* but the reputation which the potato has always had for being difficult to infect, and the poor symptom-expression, have prevented a proper realisation of the fact: while the large size of the plants, and the frequent necessity to retain them for long periods in order to obtain tubers, make isolation more difficult.

Actually, no controlled experiments to test the spread of virus X in virological glass-houses have previously been carried out, probably largely owing to the influence of the extensive early experiments of Schultz and Folsom (19) (who summarise previous work) on the transmission of "mosaic" or mild mosaic by tuber, root, and shoot contact in houses and cages in the absence of aphids, all of which proved negative; although in portion of the later experiment considerable transmission was obtained using mosaic of several types as a source, in a house where no aphids were seen but where thrips were present and the foliage was in contact (20). This work, however, has no connection with the spread of virus X, because all the plants used probably contained the latent virus, and it relates principally to viruses identical with or related to A, which accentuate the latent virus to cause mild mosaic or crinkle (17, 7), and which are transmitted by *Myzus persicae,* but not readily by means of sap or by contact (13).

The spread in the field of the American latent potato virus, which corresponds in part to virus X (17, 7), has recently been studied. Dykstra (5) stated in 1933 that of six plants of *Datura Stramonium* and six of *D. tatula* planted in a potato field, every one contracted the latent virus from the apparently healthy potato plants, but "it was not determined whether this transmission was due to insect transfer or to other means, such as the processes of cultivation or mechanical contact of leaves caused by the wind." No particulars about the distance of planting or the amount of leaf contact, of which apparently there was some, were given. Evidently the possibility of transfer by non-living agents was considered in this case. In a similar experiment in England, Smith (23) also obtained some evidence of the spread of virus X in the field to tobacco plants.

Schultz, Clark, Bonde, Raleigh, and Stevenson (21) noted that potato seedlings which were free from latent mosaic[1] but tolerant of it contracted that disease when grown for a single year in the field in contact with Green Mountain plants carrying latent mosaic, while a highly resistant seedling (S 41956), and resistant ones like S 42667 (Katahdin), contracted no infection and very little, respectively, under the same conditions over a series of years.

[1] The authors state that this term is used not to indicate a single virus, but that it may include several viruses. For the most part it appears to correspond to virus X in the present context, probably with much virus B in addition (17, 7).

It was concluded that, as the vector for latent mosaic had not been found, it was very possible that contact of diseased with healthy plants in the field might transmit the disease, and that such transmission might occur more readily in some varieties than others, the latter being the resistant seedlings referred to above. It was noted in the case of the resistant seedling 42667, which developed top necrosis on artificial inoculation with latent mosaic, that this condition was never seen during growth for 10 years in the plots, and this was attributed to the absence of the vector of X, it being considered "probable that in the presence of the insect vector, yet to be found, latent mosaic will be a serious factor in varieties manifesting it as a top necrosis."

In later work by Schultz, Clark, Raleigh, Stevenson, Bonde, and Beaumont (22), which was not seen until the present experiment was in progress, 65 plants, each of an X-free susceptible seedling, of the highly resistant Katahdin, and of the apparently immune S 41956, were grown (*a*) alternating in the same row with Triumph plants containing latent mosaic, and (*b*) an equal number in rows "not adjoining" latent mosaic plants, the distance apart not being stated. Twelve plants of each variety in the latter lot were brushed with Green Mountain foliage containing latent mosaic. The treatment of the balance of the plants in this lot is not given, nor is their final state of health referred to. Neither Katahdin nor S 41956 contracted the infection in any case, but the susceptible seedling contracted 70 per cent. of latent mosaic when grown in contact with the diseased Triumphs, and 58 per cent. when brushed with the Green Mountain foliage. It was concluded, therefore, that the susceptible seedling readily contracted latent mosaic when grown in contact with plants containing that disease or when brushed with diseased foliage.

No conclusion as to the exact means by which the infection was contracted was drawn from this very suggestive work, which had for its primary object the establishment of the occurrence of resistance to the latent virus in certain seedlings. It is clear, however, that opinion was coming round to the view that proximity alone might be sufficient, but it is impossible to say whether the infection was due to leaf contact *per se* or to proximity, which would facilitate transfer as by a vector, or to contact of the roots, or whether in the leaf-brushing test it was due directly to touch or indirectly to the transfer of viruliferous insects.

There is little room for doubt that contact of the foliage will be found to account for most if not all of the spread of virus X, and it remains to be determined whether any other agency, such as man, animals, or implements, or any vector, may be implicated as well. If not the spread will be more strictly and regularly local even than in the case of a virus disease such as leaf roll transmitted solely by slow-moving aphids (16), and much more so than a disease, such as spindle tuber, transmitted by active insects (largely grasshoppers *Melanoplus* spp.) (8). The progress of the disease from any given centre should, therefore, be more strictly continuous. On the assumption that susceptibility does not vary during the season, the rate

of advance in any one direction would be constant, and the linear spread directly proportional to the time since infection began. On the further assumption, which may be made provisionally for the purpose of the present discussion, that the spread takes place equally across and along the drills and to all four points of the compass, the number of plants contracting the infection in a unit of time (i.e. the rate of spread) would form an arithmetical series with a difference of 4, 5, or 6, and would be proportional to the perimeter of the diseased areas. Contrary to expectation, the total number of diseased plants (or in other words the diseased area) would not increase as the square of the time or distance, because the area would not remain rectangular, but would be expected to approximate to an oval. The spread of the disease would also be independent of seasonal and œcological effects on insect population. More important still, the spread would be likely to take place in all potato districts, good and bad, though not necessarily to the same extent in all countries. Another deduction of great practical import would be that infection centres within a potato crop would be more dangerous than those outside it, and that in the absence of these it might be much easier than had been supposed to maintain potatoes free from virus X. This view is in harmony with other work. Jones and Vincent (9) grew virus-free Early Rose in isolation of half a mile for three years, after which the percentage of the veinbanding virus was 100, but no other virus was noted. Champion potatoes have been grown in Donegal in very moderate field isolation for six years without contracting any virus infection, although X is known to spread freely within potato crops there (4, 14). This is an added reason for maintaining the absolute purity of special stocks and new varieties. This result also probably exculpates the local arable flora, in which there are no Solanaceous plants, from harbouring virus X, but the situation elsewhere is different (5, 24).

In the present experiment virus F spread by leaf contact as well as X. This is not unexpected, for the virus is easily sap-transmissible (3), and contact is probably the usual method of spread in Nature. The virus, however, has been transmitted by *Myzus persicae* under certain conditions, that is in the presence of virus A (3), and there are, therefore, two natural methods of transmission. The same probably holds for some other potato viruses, notably virus Y, which is highly infectious, and has been found by McKay and Dykstra (13) to spread by leaf contact in cages in the absence of insects. Under the same conditions there was no spread of other mosaics or leaf roll, but giant hill spread when the soil was cultivated. The possible spread of virus Y by leaf contact from and to more or less tolerant varieties like Arran Crest is of practical importance in first-class seed potato districts where *Myzus persicae* is scarce or absent.

It is likely, therefore, that some of the potato viruses are for practical purposes exclusively transmitted by leaf contact or similar mechanical means as virus X and the Up-to-Date streak complex designated X + B; some by insects, or biologically, as well as mechanically, with mechanical transmission

predominating, as virus F; some by both means, but with biological transmission probably predominating, as virus Y; and some by biological means alone, as leaf roll and possibly virus A.

Summary.

Simple mosaic caused by virus X (or Solanum virus 1) was contracted readily by potato plants growing in an insect-proof glass-house when their haulms were in contact with those of potato plants containing that virus. No infection was contracted by plants derived from portion of the same tubers and grown in the same house when the haulms were separated from those of diseased plants by cylinders made of half-inch mesh wire netting.

The amount of infection was considerably increased by allowing a fan to play on the foliage so as to increase leaf contact.

No infection took place through the roots even when a diseased and a healthy plant grew in the same pot.

A similar result was obtained from plants grown in the open, infection with virus X (Solanum virus 1) being contracted when foliage was in contact, but not when it was kept separate by half-inch mesh wire-netting cylinders, even though the plants were the same distance apart and there was free access for insects above and below ground.

Virus F (Solanum virus 8) was transmitted by leaf contact in the glass-house under the same conditions as virus X (Solanum virus 1).

A case is described of the accidental transmission of Up-to-Date streak (virus B or X + B; Solanum virus 4, or 1 and 4) in an insect-proof house, presumably by leaf contact.

A mixture of viruses like X and F (Solanum viruses 1 and 8) may become separated following mechanical transfer, even though the plant which contracts infection is susceptible to both. The Up-to-Date streak complex has not been observed to segregate.

The view that virus X (Solanum virus 1) spreads mainly by leaf contact is supported by general experience in the field, but the possibility of other mechanical transmission, or of insect transmission, is not excluded.

There is evidence that some viruses are transmitted in Nature by biological as well as mechanical means.

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No. 2.

A STUDY OF THE INFILTRATION OF VIRUSES INTO SEED POTATO STOCKS IN THE FIELD.

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Introduction.

It has been known as the result of previous work carried out in this laboratory that the potato mosaic diseases occurring in Ireland are simple mosaic, caused by virus X (13), veinal mosaic caused by virus A (13), leaf-drop streak caused by virus Y, tuber blotch caused by virus F (10, 3), aucuba mosaic caused by virus G (3), crinkle caused by the combination X + A (13), interveinal mosaic caused by X + F (10), rugose mosaic caused by X + Y, and double virus aucuba mosaic caused by F + A (3). Virus B (20), i.e., the "streak" virus carried by Up-to-Date, is also familiar in Ireland, although not as the cause of any specific disease in the field, for it always occurs in the latent state, and so far has not been found free from virus X. Virus E (paracrinkle (15)) is known only in the latent form in the variety King Edward, which is not grown to any extent in Ireland. Besides the mosaic diseases, leaf roll also occurs, and there are other minor diseases, such as witch's broom (14) or wildings.

It was known in general terms that the principal viruses underlying the mosaic diseases were X, A, Y, F, and B, acting singly or in combination, but the relative prevalence and economic importance of each virus were not known, nor the rates at which they would be likely to spread.

About three years ago, therefore, it was decided to secure some data concerning the type and degree of virus infection arising in potato stocks grown in a district where the production of seed is an important industry. Such an investigation naturally necessitated a knowledge of the state of health of the stocks when first planted in the particular district. For some years, however, tested units of different potato varieties have been sent from the Albert College, Glasnevin, to the Department of Agriculture for propagation in Co. Donegal, on the N.W. coast of Ireland, and ultimate distribution to the seed potato growers, and these stocks, or crops descended from them, were at our disposal for the investigation. The choice of varieties was limited, in so far as it was desired to examine those which would be susceptible and tolerant to

the principal mosaic viruses, and, therefore, liable to contract any of the latter which might be spreading in the district.

Champion and Arran Banner were two available varieties which fulfilled these conditions, and were accordingly selected. The reactions of both to the mosaic viruses are very similar, and may be summed up as follows:—

X (Solanum virus 1 (21)). Mosaic mottling of the foliage, the intensity of which depends upon the strain of virus.

Y (S. virus 2). Distinct mottle and some rugosity. Streaking of underside of veins (with leaf-drop streak in A. Banner) in 1st year of infection.

A (S. virus 3). Diffuse veinal mottle with some reduction in size of leaflets.

B (S. virus 4). Carried symptomlessly.

E (S. virus 7). In Champion severe mottle, waviness and distortion of leaves. Growth stunted. (Symptoms in A. Banner not known.)

F (S. virus 8). Foliage symptoms absent or consisting of inconspicuous yellowish spots on lower leaves. Tuber necrosis in Champion (3).

G (S. virus 9). Conspicuous yellow spots or blotches on lower leaves. Tuber necrosis in Champion.

X + A. Crinkle, i.e., pronounced mottle with puckering and reduction in size of leaves. Growth stunted.

X + F. Pronounced interveinal mottling accompanied in the lower leaves by rusty necrosis. Tuber necrosis in Champion.

A + F. Bright yellow aucuba-like mottling of the foliage. Tuber necrosis in Champion.

History of the Champion and Arran Banner Stocks studied in the investigation.

Champion is an old variety introduced to Ireland about 1876. It became so popular that for 20 years it occupied 75 per cent. of the total acreage under potatoes in the country. Towards the end of the century it began to deteriorate because of virus infection, and eventually all crops were characterised by reduction in vigour, puckering and reduction in size of leaf, and marked susceptibility to blight (4). An attempt to rejuvenate the variety was initiated in 1922 by officials of the Department of Agriculture—first, by propagating bulk selections from the best-looking crops in Ireland and Scotland, and then, as these results were unsatisfactory, by selecting individual healthy-looking plants, some of which (ex Scotland) were tested at Glasnevin for virus infection in 1925. The latter proved to be healthy, and the present virus-free stock at Glasnevin, as well as the stocks now being propagated by the Department of Agriculture, to which this work relates, are descended from some of these units. Arran Banner, a comparatively new variety, was introduced in 1926–1927, and

is very popular in Great Britain and Ireland on account of its high cropping capacity. Tubers were first received at Glasnevin in 1927, and the present virus-free stock is descended from some of these.

Tested units of both varieties were sent to Donegal in the autumn of 1928 and in that of 1931, where they were at first propagated in small plots at Dungorman by officers of the Department of Agriculture, and afterwards distributed to potato growers in Donegal and elsewhere. Previous to 1928 potatoes were examined for absence of virus diseases at Glasnevin by grafting on President and Arran Victory supplemented by observation. Viewed in the light of present knowledge this technique would be considered inadequate, particularly in the case of mild strains of virus X, but a worse drawback was that owing to its slowness and limitations of space it could not be repeated often enough, and too much reliance was placed on the protective power of glasshouses. Although the significance of latent X infection was well understood, and every effort was made to eliminate it, with such success that many of the present collection of virus-free varieties date back to that time, nevertheless the absolute health of stocks sent out in 1928 cannot be guaranteed unless the units included are still represented and in a virus-free condition at Glasnevin. It is unfortunate, therefore, that one unit of Champion and one of Arran Banner were dropped accidentally between 1928 and the present time.

The information available at the present time regarding these stocks is as follows :—

A. *Champion nucleus stocks sent to Donegal in 1928.*—Three units of three tubers each were sent, of which two units are still virus-free at Glasnevin. The third unit was dropped accidentally, but a related plant gave a crinkle reaction with A-infected Irish Chieftain, indicating that it contained X, and the unit is, therefore, under suspicion. This stock was, therefore, at least 66 per cent. virus-free.

B. *Arran Banner nucleus stocks sent to Donegal in 1928.*—Two units of six tubers each were sent, of which one is still present in a virus-free condition at Glasnevin. The other was dropped, but nothing is known against the state of its health. As will be seen, however, the simplest, though not necessarily the only, explanation of the results would be to assume that this unit contained virus X, and in any case the stock can now be guaranteed virus-free only to the extent of 50 per cent.

C. *Champion nucleus stock sent to Donegal in 1931.*—Two units of four and six tubers, respectively, were sent, both of which are still virus-free at Glasnevin. The original stock was, therefore, entirely virus-free.

D. *Arran Banner nucleus stock sent to Donegal in 1931.*—Two units of four and six tubers, respectively, were sent, both of which are still virus-free at Glasnevin. The original stock was, therefore, entirely virus-free.

It may be added that of the known potato viruses only a masked virus X could have been present in the uncertain units of the 1928 stocks without being detected by the method of testing used. At the present time a representative of every unit sent out is retained at Glasnevin and tested annually.

Examination of Potato Stocks sent to Donegal in 1928.

The testing of these stocks was carried out over two years—Champion being examined in 1935, and Arran Banner in 1936. Samples were obtained from four different crops of Champion and five different crops of Arran Banner grown in Co. Donegal, and all descended from the original tested tubers sent to Donegal in 1928, and propagated with "health stocks" of other varieties at Dungorman. It may be mentioned that the presence of a latent virus in some of the latter cannot be ruled out, as they were not all propagated from tested seed. The varieties, however, are grown separated from one another, usually by 4–5 drills of turnips, in an isolated field.

Table 1 shows the conditions under which the stocks were grown at different farms after propagation at Dungorman. Crops stated to have been grown under supervision were destined for seed purposes, and were, therefore, subject to inspection by officials of the Department of Agriculture. From such crops rogues or unhealthy plants might be removed by growers, provided they occurred only in small numbers, so that their removal would not detract from the well-cultivated appearance of the crop.

In addition to those descended from the 1928 nucleus stocks, two other crops of Champion (sample lots V and VI) were examined for comparison. Lot V represented a stock which had been grown on the same farm in Co. Donegal for about 20 years. It was not isolated from crops of various other potato varieties during that time, and was not intended for seed purposes. Lot VI was the only sample not grown in Donegal. It came from a stock which had been sent from Donegal to Athlone (in the midlands) in 1928, and was descended from some of the original untested selections of Champion made in 1925 at the time of the rejuvenation experiment. It was grown in isolation in Athlone in 1928, but showed "mosaic," and following this was not isolated, and was not certified for seed purposes.

Method of Testing.—Each sample lot comprised 50 tubers, which were taken at random from the crops in January. It was considered necessary in the beginning to make the test as comprehensive as possible, and, accordingly, in the examination of Champion in 1935 each was tested on four different potato varieties, viz., Arran Crest, Arran Victory, Up-to-Date, and President, following Bawden's scheme (20, p. 324), except that Arran Crest was used instead of Epicure. Inoculations to *Datura Stramonium* were also carried out, and it was reckoned that viruses X, A, Y, B, E, G, and leaf roll could be conclusively identified by a characteristic reaction on one or more of these hosts. The

Table 1.

Results of testing different potato crops descended from nucleus stocks sent to Donegal in 1928.*

Variety.	Sample.	Growth conditions following propagation at Dungorman.		Year of test.	No. of plants tested.	Total number of plants per cent. infected with—							
		Isolated at least 50 yards from other potato crops until end of—	Number of years grown subsequently under other conditions.			X	A	Y	B	G	E	F	Leaf roll.
Champion	I	1934	0	1935	50	40	2 (+X)	0	0	0	0	0	0
,,	II	1933	1 year under supervision; 10 ft. from commercial Kerr's Pink.	1935	50	66	0	0	0	0	0	0	0
,,	III	1932	2 years under supervision; 10 ft. from commercial King Edward.	1935	50	62	4 (+X)	0	0	0	0	0	0
,,	IV	Not isolated as above.	3 years without supervision amongst various potato crops of doubtful health.	1935	50	46	6 (+X)	0	4 (+X)	0	0	0	0
,,	V*	—	20 years at least without supervision amongst various potato crops of doubtful health.	1935	50	4 (+A)	100	6 (+A)	0	0	0	0	0
,,	VI*	—	6 years without supervision (in Midlands). Not isolated from other potato crops.	1935	50	4 (+A)	96	0	0	0	0	0	0
A. Banner	VII	1935	0	1936	50	94	0	0	0	0	0	—	0
,, ,,	VIII	1935	0	1936	50	65	0	0	4 (+X)	0	0	—	0
,, ,,	IX	Not isolated as above	5 years without supervision under ordinary farm conditions.	1936	50	40	0	0	4 (+X)	0	0	—	0
,, ,,	X			1936	50	38	0	0	0	0	0	—	0
,, ,,	XI			1936	50	72	0	0	0	0	0	—	0

* Lots V and VI were not descended from 1928 nucleus stocks. See p. 20.

identification of virus F was not considered in outlining the method, as this virus was not described until 1936 (10). Its presence is demonstrated by the production of tuber symptoms in certain varieties, which include President, Arran Victory, and Champion. The fact that Champion tubers were free from necrosis was, therefore, taken as proof later that F was not present in them, but as the tubers of the President and Arran Victory plants used in the tests were not retained for examination, no statement regarding F in Arran Banner can be made.

All the tubers were numbered and cut in two, one set of half tubers serving as controls. The remaining halves were planted in the greenhouse where the grafting and inoculating operations were carried out. When the scions were established the grafted potato plants were removed from the greenhouse, allowed to harden for a few days, and then transferred to a special plot out of doors. Here they were planted, with the corresponding controls, in sequence in long drills, so that each Champion (or Arran Banner) source was parallel with the plants on which it had been grafted and their controls. Each of the plants under test was inoculated to at least two *Datura Stramonium* plants.

Results.—The results are shown in Table 1. Leaf roll, viruses G and E and, in the case of Champion, virus F were absent from all lots. Virus B occurred in small amounts in two lots of Arran Banner and one lot of Champion, and was accompanied by X in every case. Virus Y, present to the extent of 6 per cent., was confined to one lot of Champion.

The most striking feature is the high figure for X in all lots descended from the 1928 nucleus stocks of both varieties. It ranges from 40 to 66 (an average of 53·5 per cent.) in the case of Champion and 38 to 94 (average 61·8 per cent.) in Arran Banner. Even assuming that the Champion and Arran Banner stocks were originally infected to the maximum extent of 33 and 50 per cent., respectively, there was still a considerable increase in the virus content, which was independent of the degree of isolation in which the crops were grown. The strain of X found in these stocks was, on the whole, exceedingly mild. It was carried symptomlessly by Champion, so that it was impossible to distinguish between X-infected and healthy plants in the field. A small number of the infected Arran Banner plants showed a mottle, but in the majority of cases no symptoms could be detected, and the presence of X was only revealed by the reactions on Arran Crest and *Datura Stramonium*. In the latter host, the symptoms mainly consisted of initial vein-clearing, followed by the appearance of pale, rounded spots or blotches in the interveinal areas; these soon merged together, and the final symptom was interveinal chlorosis, and dark green banding of the veins.

Virus A occurred only to a very limited extent in the 1928 stocks, probably due to absence of sources of infection, but the two poor Champion lots (V and VI) were conspicuous by the fact that they were permeated with this virus. In the field, the A-infected Champion plants showed a mild, but clearly visible, diffuse veinal mottle accompanied by some reduction in size of the

leaflets; the Up-to-Date plants on which they were grafted developed acronecrosis. Lot V was intended to represent some of the old degenerate Champion, which was stated to be practically 100 per cent. infected with mosaic (4). The picture presented by these degenerate Champion stocks apparently corresponded in general to mild crinkle or pronounced simple mosaic infection, but the actual viruses were never exactly determined. It was surprising to find so much veinal mosaic due to virus A in lot V, and, so far as the crop is representative, it may indicate that this virus was responsible for a considerable amount of the moderate mosaic which the old Champion eventually showed throughout the country. The stock represented by lot VI originated from a field selection made in 1925, and must have been free from visible mosaic at that time. By 1928 there was a general development of mosaic throughout the stock, which the present work shows to have been due almost entirely to virus A. The available evidence indicates that this must have been contracted in Donegal, although the circumstances are not known, and it appears, therefore, that aphid-borne viruses can spread there if sources of infection are present. Presumably this stock was grown near an infected crop some time before 1928.

The absence of virus X from lots V and VI is striking. It must be assumed that potato stocks can be grown under ordinary farm conditions for a number of years (at least 20 in the case of lot V) without contracting more than 5 per cent. of infection, probably due to the absence of direct contact with the disease, but under the same conditions they may contract 96 to 100 per cent. of A infection, depending upon the crops in the immediate vicinity. It is to be expected, where this virus and Y are concerned, that the infection could be brought in from outside the crop and that the resulting degeneration would be more rapid than in the case of X.

Virus Y occurred only in Champion lot V. It is evidently not common in Donegal, but it was isolated a few years ago from mosaic Arran Crest plants growing there. In the tests it was identified by the reaction on President, which showed leaf-drop streak, and, since the corresponding Up-to-Date plants developed acronecrosis, it was concluded that virus A was present in addition. Dark green vein-banding was produced in tobacco in a confirmatory test. The symptoms of Y (+ A) in Champion itself consisted of a pronounced veinal mottle and some rugosity and reduction in size of the leaves, and were similar to, but more intense than, the symptoms of A alone. No streaking of the veins was visible, although this symptom occurs in the first year of infection with Y in the greenhouse. Apparently second-year symptoms of Y on Champion are comparatively mild.

It will be seen from the table that virus B was contracted in small amounts in three crops, and in each case was accompanied by X. No insect vector of B has been discovered, but there is evidence that it spreads under the same conditions as virus X (11). Clinch and Loughnane (2) have shown that it is readily transmitted by sap inoculation from Up-to-Date to other solanaceous hosts, but not to intolerant varieties of potato, such as President and Arran

Victory. Tolerant potato varieties were not tried, but it is probable that they could be successfully inoculated.

Examination of Potato Stocks sent to Donegal in 1931.

For this examination samples were obtained from seven different crops of Champion, all grown in Co. Donegal, and descended from the 1931 nucleus stock. The particulars of the conditions under which the different crops were grown after distribution from Dungorman are described in Table 2. Only one crop of Arran Banner, authentically descended from the 1931 stock, was available, and this was the nucleus stock still growing in the propagation plots at Dungorman. A crop of Arran Chief growing at Dungorman and descended from a single virus-free unit sent there in 1931 was included also. This variety resembles the other two in its reactions to X, Y, A, and G. Like Champion, it is severely affected by virus E, but the reaction to F is not known.

Methods.—It was considered unnecessary in these particular tests to follow the laborious procedure adopted in the examination of the 1928 stocks. Experience had shown that absence of symptoms in Champion and Arran Banner precluded the presence of leaf roll, Y, A, G, and, in the case of Champion, of E and F also. Accordingly, it was decided that a careful examination of the sources combined with a specific test for latent X would give a good deal of information, and supplemental tests could be carried out if necessary. It was realised that virus B could not be detected in this way, but as the virus has never been found to exist or spread apart from X, it was considered to be comparatively unimportant from the practical point of view.

Champion lots XII and XIII were tested by core-grafting each tuber into two Arran Crest and two Up-to-Date tubers, the reactions of these varieties being diagnostic for X and A, respectively. Lots XIV and XV and Arran Banner lot XIX were top-grafted on Arran Crest in the greenhouse, while Arran Chief lot XX was top-grafted on Up-to-Date in addition. In all cases the sources as well as the grafted plants were grown and carefully watched for disease symptoms throughout the season. Champion lots XVI, XVII, and XVIII were obtained early in September, 1937, from growing crops, in which, according to Inspectors, not a single unhealthy plant had been seen at any time during the season. Samples of leaves were taken from plants at random throughout these crops; they were cut with sterilized blades, placed in clean envelopes, and transmitted to the laboratory, where they were received the following day. Each leaf sample was inoculated to three *Datura* plants in the greenhouse, and, as a check, similarly treated leaves from plants infected with latent X were inoculated in a parallel series. All the check *Datura* plants developed mosaic symptoms in 8–12 days, proving that the delay between the cutting of the leaves and inoculation did not destroy the infectivity of the virus. Actually it has been proved that X survives for at least 46 days in dried leaves (1).

TABLE 2.

Results of testing different potato crops descended from nucleus stocks sent to Donegal in 1931.

Variety.	Sample lot.	Conditions under which stock was grown.	Year of test.	No. of plants tested.	Total number of plants per cent. infected with—							
					X	A	Y	B	G	E	F	Leaf roll.
Champion	XII	Nucleus stock grown for 4 consecutive years at Dungorman.	1936	34	0	0	0	—	0	0	0	0
,,	XIII	Same as XII until 1934. During 1935 grown elsewhere, under supervision, and separated 100 yards from commercial crops.	1936	50	0	0	0	—	0	0	0	0
,,	XIV	Nucleus stock grown for 5 consecutive years at Dungorman.	1937	50	0	0	0	—	0	0	0	0
,,	XV	Progeny of stock represented by XIII, and grown at same farm, and under same conditions, in 1936.	1937	50	0	0	0	—	0	0	0	0
,,	XVI	Same as XII until 1934. Following 3 years grown elsewhere, under supervision, separated at first by 50 yards, and in final year by 3 yards, from commercial potato crops.	1937 (Sept.)	90	0	0*	0*	—	0*	0*	—	0*
,,	XVII	Same as XIV until 1935. Following 2 years grown under supervision, and separated 50 yards from commercial crops.	1937 (Sept.)	35	0	0*	0*	—	0*	0*	—	0*
,,	XVIII	Same as XV until 1936. In 1937 grown elsewhere, under supervision, and separated 50 yards from commercial crops.	1937 (Sept.)	35	0	0*	0*	—	0*	0*	—	0*
A. Banner	XIX	Nucleus stock grown for 4 consecutive years at Dungorman.	1937	50	4	0	0	—	0	—	—	0
A. Chief	XX	Nucleus stock grown for 4 consecutive years at Dungorman.	1936	25	4	0	0	—	0	0	—	0

* Observations made by Inspectors of the crops in Donegal.

Results.—The results are shown in Table 2. In the case of Champion, every one of the 184 plants grown at Glasnevin (lots XII, XIII, XIV, and XV) was vigorous and apparently healthy, the tubers were sound, and no symptoms appeared in the Up-to-Date plants on which some of them were grafted. As already mentioned, no mosaic or other disease symptoms had been observed by Inspectors or growers of the Donegal crops represented by samples XVI, XVII, and XVIII, so that all these Champion plants were presumably free from leaf roll, Y, G, A, E, and from F also in the case of lots XII, XIII, XIV, and XV. The outstanding feature of the results, however, was the complete absence of latent X from every sample; for all the grafted Arran Crest plants remained healthy, and not a single plant of *Datura Stramonium* inoculated from the 160 leaf samples showed mosaic symptoms. This was in contrast to the high X-content of lots I to IV of the 1928 stock which were grown in the same district in Co. Donegal. The difference is without doubt attributable to the fact that X must have been present in the 1928 stock to begin with. Clearly, if sources of X are present within a crop, the virus spreads from the infected to healthy plants, but otherwise there may be no spread of the virus even though infected crops are growing in the same vicinity. Lots XIII and XV were grown 100 yards away from an X-infected crop of Champion in 1935, whilst only a few yards separated lot XVI from a commercial crop of Arran Banner during 1937. Sources of X, therefore, were almost certainly present in the neighbourhood, and the failure, in spite of this, to find a single X-infected plant is noteworthy.

The 50 plants of Arran Banner (lot XIX) all appeared healthy, and the presence of leaf roll, Y, A, and G, was, therefore, excluded, but the variety contained 4 per cent. of latent X infection. Arran Chief (lot XX) also contained 4 per cent. of latent X, but no other virus was evident. The absence of B and F was not established in these two cases. In view of the results with Champion, it was disappointing to find any X at all, as both stocks were virus-free originally, and had been grown continually at Dungorman since 1931. It does not follow, however, that because the infection occurred there the virus must necessarily have been borne from a considerable distance. It has been mentioned previously that some of the varieties grown at Dungorman may be infected with latent virus, and, although they are separated from one another, it is possible that in the working of many small potato plots amongst turnips the degree of isolation is insufficient to prevent some transmission by horses or implements if individual plots are infected.

The absence of insect-borne viruses from all the 1931 stocks (Table 2) is remarkable. Leaf roll sources were absent from the vicinity, but A is not uncommon in Donegal, and there is some Y also. In such an area, where aphids are usually scarce or absent and sources of infection not abundant, it appears that even the very moderate degree of isolation in which some of these stocks were grown at times was sufficient to exclude the insect-borne viruses completely.

Discussion.

The spread of viruses in potato stocks naturally depends in the first instance upon the presence of sources. After that it will depend upon the mode of dissemination of the virus, and the reaction of the variety of potato. The leaf roll virus is the simplest case. It is transmitted by certain species of aphids, all known varieties of potato are susceptible to it; therefore, if sources and insect vectors are present, the virus is certain to spread to some extent to all varieties of potato. In the absence of vectors the virus cannot spread, so far as is known. The same may be true of virus Y, although in this case the possibility of spread by contact as well as by insects cannot be excluded (11). The virtual absence of leaf roll and Y in Irish seed potato districts is due to scarcity both of sources and vectors.

Infection by virus A will also depend upon the presence of sources and vectors, and, incidentally, sources of this virus are less likely to be eliminated by rogueing than leaf roll or Y, because of the comparatively mild symptoms. Another factor, however, plays an important part in the case of virus A—namely, the manner in which different potato varieties react to the virus, for only those varieties which are tolerant, i.e., do not react with streak, become permanently affected in the field (12). The varieties examined in this work are all tolerant of A. Nevertheless, amongst the stocks originally free from A (the 1928 and 1931 stocks) there was very little spread of this virus. This cannot be attributed to entire absence of sources, but is probably a result of the combined effects of scarcity of sources in the vicinity and, as already suggested, low aphid population. Champion lot VI, although belonging to a stock which was presumably healthy prior to 1928, contracted what was proved to be virus A infection in that year, probably from being grown too near an infected crop, and by 1935, if not sooner, the virus had infected practically every unit. It is impossible to say over what period, or in what circumstances, the stock represented by lot V incurred 100 per cent. infection with virus A, as no precise information regarding its original state of health is available; but the presence of 6 per cent. of virus Y may indicate infection outside Donegal.

The principal virus found in the stocks originating from tested tubers was X. The 1928 stocks of Champion and Arran Banner showed an average of 53·5 per cent. and 61·8 per cent., respectively, in the crops examined. Allowing that these stocks were infected to a certain degree in the nucleus stage, and that, as the virus showed no symptoms, the infected plants would have been propagated at about the same rate as the healthy, there was still an undoubted spread of X, which was independent of the degree of isolation in which the crops were grown in later years. On the other hand, no X was found in the 1931 Champion crops, some of which were grown latterly on the same farms and under the same conditions as the 1928 stock. A small amount of X infiltrated into the Arran Banner and Arran Chief stocks which had been

grown continuously at Dungorman, but here the conditions are somewhat specialized, as already pointed out. Under ordinary field conditions it is clear that X spreads if sources of infection are present within the crop, but otherwise no infection whatever with this virus may occur.

This result supports the theory advanced by Loughnane and Murphy (11) that the main spread of X in the field takes place as a result of contact between diseased and healthy plants, although infection from a greater distance is not excluded. They showed experimentally that X is spread by the touching of the aerial portions of plants under circumstances excluding insect participation. No infection took place unless the tops of the plants were actually in contact, and the process was much facilitated by the action of wind in brushing the leaves together. Contact below ground did not produce infection. Schultz and his co-workers (19) also obtained a high degree of X infection in the field when healthy plants were either grown alongside diseased plants or had their tops brushed with infected foliage. Jones and Vincent (6) grew a stock of virus-free Early Rose in the field during three consecutive years, and isolated at least a half-mile from other potatoes. During that time the stock contracted 100 per cent. of the insect-borne vein-banding virus but no X, although it was shown to be susceptible to artificial inoculation with X.

If, as the evidence suggests, the main spread of X in the field depends upon contact between healthy and infected plants, it should be comparatively easy to build up and maintain potato stocks in an X-free condition under field conditions even in districts where aphids are prevalent. Propagation from tested X-free units would be the first essential, and with moderate isolation and absolute absence of volunteer plants, there is little reason to expect that X infection would occur. Some varieties of potato, of course—e.g., Arran Crest, Epicure, and King Edward—never become permanently infected with X in the field because they are intolerant of the virus, but most of the best potato varieties are susceptible and easily infected.

The desirability of producing X-free seed potato stocks does not appear to be a matter of general agreement. In the first place, it is generally supposed that the difficulties are too great. The idea is held also that a mild form of X infection may be advantageous because of itself it exercises little or no harmful effect on the plant, while it protects against further infection with severe form of X which may seriously reduce yields. This undoubted benefit, however, would only be gained wherever plants were exposed only to infection with severe X, and the benefit would be still more restricted if the mottle types of X did not protect against the ringspot types (7). On the other hand, infection with even a mild form of X is potentially dangerous, because it aggravates the effects of other viruses, including A and F which are insect-borne. Dykstra (5) believes also that X aggravates the effects of Y and leaf roll. In combination with A, virus X forms crinkle, a disease which in Ireland is one of the principal causes of degeneration. Fortunately, certain varieties like Kerr's Pink, British Queen, and Up-to-Date do not develop crinkle in the field, because they are

intolerant of A, and this probably explains why they have flourished so well in this country. Finally, one must consider the possibility, however remote, that a mild form of X might under any circumstances become virulent, for at the present time the manner in which different virus strains arise is not understood. It has been shown, for instance, in the case of curly top of sugar beet that passage of the attenuated virus through a susceptible species of host plant causes a restoration in virulence (8, 9), and a similar change might be induced in other simple ways. There is, however, no actual evidence of a mild virus becoming virulent under natural conditions, and it is possible that the infection of stocks with mild strains of viruses may yet be developed as a method to prevent infection with more serious disease (15, 16). Viruses, however, are at present only known to "protect" against their own different strains, so that deliberate infection of a stock with a mild virus would be advantageous in a district where severe forms of the same virus were prevalent, but if the stock were to be grown in other districts would be highly undesirable, leading to the occurrence of virus combinations. The continuance of the present policy in this country (from which seed is exported to many different parts of the world) of building up seed potato stocks free from all viruses, including latent X, is considered to be preferable, and the results of this work and new knowledge concerning the method of spread of virus X tend to dispel the idea that the control of X is impracticable.

American workers are engaged upon the difficult task of breeding potato varieties resistant to virus infection, and at the same time possessing other characters that are desirable from the economic point of view. They have recently developed a variety which is immune to virus X both in the field and in inoculation experiments in the greenhouse (18). A point of great practical importance to the breeder which has been referred to by Murphy (12) is that varieties which react with top-necrosis to a given virus when artificially infected in the greenhouse do not appear to contract that virus in the field, and, therefore, from the growers' point of view, are immune to that virus. Certain new varieties of commercial value of which virus-free stocks are being propagated in Ireland have been found to react with top-necrosis to virus A, and, like Kerr's Pink and some other of the older varieties already mentioned, are "field-immune," and, therefore, suitable for growing in districts where A is prevalent. Attempts to find varieties immune to Y (veinbanding) and leaf roll have been unsuccessful, and at the present time the best varieties to employ where infection with these viruses is liable to occur are those which are most tolerant to them, and do not harbour a latent virus, which may aggravate their effects.

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Summary.

Four different crops of Champion and five of Arran Banner potatoes, all descended from two stocks of these varieties tested by grafting on President and Arran Victory before 1928, and then believed to be virus-free, showed in every case, after being grown in the field in Donegal for 5 to 7 years, much latent X infection (Solanum virus 1), irrespective of the degree of isolation in which they were grown. The amount of infection was 40 to 66 per cent. in Champion, and 38 to 94 per cent. in Arran Banner. Virus A (Solanum virus 3) occurred in three crops to the extent of 2 to 6 per cent., and virus B (Solanum virus 4) in three crops to the extent of 4 per cent., these being accompanied by X in all cases. No other virus was present.

Seven different crops of Champion potatoes descended from a stock which was proved to be virus-free in 1931, showed in every case, after being grown in moderate commercial isolation in the field in Donegal for 4 to 6 years, complete freedom from viruses X, A, Y (Solanum virus 2), G (Solanum virus 9), E (Solanum virus 7), F (Solanum virus 8), and leaf roll.

The initial X infection in the two earlier stocks of Champion and Arran Banner is believed to have been present at the time these stocks were propagated. Champion may have been infected to the maximum extent of 33 per cent. and Arran Banner 50 per cent., the remaining disease representing subsequent spread within the crop.

Infection within a crop or by contact is very important, and in its absence it is possible to maintain potatoes free from virus X and other similar viruses by means of moderate isolation; freedom from insect-borne viruses can also be achieved in a district like Donegal, where these viruses and their vectors are at a minimum.

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No. 3.

REPORT OF THE IRISH RADIUM COMMITTEE FOR THE YEAR 1937.

[Read JUNE 24. Published separately JULY 6, 1938.]

THE issue of capillary tubes containing radon for therapeutic purposes has proceeded without interruption throughout the year, 1,526 tubes containing 10,110 millicuries having been issued, as compared with 1,793 tubes containing 12,635 millicuries issued in 1936, and 2,540 tubes containing 16,581 millicuries in 1935.

Dr. J. M. Hennebry was awarded the Radium Exhibition falling vacant during the year.

The number of cases of Malignant Disease treated with radon or radium during the year was:—

St. Anne's Hospital, Dublin	247
City of Dublin Skin and Cancer Hospital	64
Central Hospital, Galway	26
Coombe Hospital, Dublin	5
County and City Infirmary, Waterford	4
Steevens' Hospital, Dublin	2
Mercer's Hospital, Dublin	2
Dr. Oswald Murphy [including cases treated at St. Vincent's Hospital, Dublin]	102
Dr. Oliver Chance [including cases treated at Coombe, Sir P. Dun's, Richmond, Rotunda, and Steevens' Hospitals] ...	50
Total, ...	502

In addition, Dr. Murphy reported the treatment of 81 cases and Dr. Chance of 16 cases of Non-Malignant Disease; Total, 97.

REPORT RECEIVED FROM THE CITY OF DUBLIN SKIN AND CANCER HOSPITAL.

(*Radiologist,* DR. F. O. PILKINGTON.)

Number of cases of all types of malignant disease seen during 1937 ...	199
Number of cases of all types of malignant disease treated during 1937	189
Number of cases of all types of malignant disease treated by Surgery alone	8
Number of cases of all types of malignant disease treated by Radium alone	23
Number of cases of all types of malignant disease treated by X-rays alone	87
Number of cases of all types of malignant disease treated by Surgery + Radium	9
Number of cases of all types of malignant disease treated by Surgery + X-rays	30
Number of cases of all types of malignant disease treated by Radium + X-rays	29
Number of cases of all types of malignant disease treated by Surgery + Radium + X-rays	3

Notes on some of the Cases.

Of the cases treated with radium during 1937, three were for carcinoma of the cervix and three for carcinoma of the skin.

Female, aged 46 years, has been suffering from carcinoma of the cervix since early in 1935, and had had previous treatment by deep X-ray and radium. She remained well till April, 1937, when the disease was found to be spreading. Radon was applied in the cervix and fornices, but although she obtained some relief of pain she died three months later.

Female, aged 62 years, had an early carcinoma of the cervix in January, 1937. After a preliminary course of deep X-rays, radon was inserted in the cervix and fornices. On discharge the cervix looked and felt healthy, but four months later the disease was found to be too far advanced to warrant her being sent back for further treatment.

Female, aged 51 years, had a large inoperable carcinoma of the cervix. After a preliminary course of deep X-rays, radon was inserted in the cervix and radium element in each fornix. Four months later the local condition was worse, and nothing further could be done for her.

Female, aged 76 years, had a squamous carcinoma on her nose. X-ray treatment in July, 1937, failed to cure the condition. A radon plaque was applied in October, and three months later there was only a scarcely noticeable scar present.

Male, aged 77 years, had a large fungating mass on his left heel. A radon plaque had no apparent affect.

Female, aged 41 years, had a carcinomatous ulcer on her leg. A radon plaque was applied in November, 1937, and when she was last seen the ulcer was healing in from the edges.

Report received from St. Anne's Hospital, Dublin.

(*Radiologist*, Dr. Oliver Chance.)

In the following tables any patient who could not be traced in March, 1938, is regarded as dead. The figures, therefore, show the crude survival rate. It must be realised that this has little bearing on the percentage of cases who were cured or died of intercurrent disease. In a number of the untraced cases there is good reason to believe that the patient is still alive and free from disease. Furthermore, it is to be remembered that 1 in 7 of our patients is over 70 years old—two patients treated recently were 91 and 92 respectively—the expectation of life in many cases is, therefore, only a few years.

When the above facts are realised it will be obvious that the cold figures which follow can give little idea of the true value of radiation, not only in curing disease, but also in relieving symptoms and prolonging life.

Malignant Cases, 1937. All Types. New Cases.

No. of Cases of all types of malignant cases seen		571
No. of Cases unsuitable		120
No. refusing treatment		10
No. of Cases treated		441
By Surgery alone	19	
„ Radium alone	213	
„ X-rays alone	162	
„ Radium and Surgery	11	
„ X-rays and Surgery	9	
„ Radium and X-rays	21	
„ Radium, Surgery and X-rays ...	0	
„ Radium and Superficial X-rays ...	2	
„ Superficial X-rays alone	4	

Malignant Cases.

(Seen for first time, 1937.)

Including all Cases, both Intern and Extern.

Intern 480

Extern 91

	No. of Cases seen.	Unsuitable for Treatment. Too advanced.	Refused treatment.	No. OF CASES TREATED.	With Radium alone.	Deep X-Rays alone.	Surgery alone.	Radium and Surgery.	Radium and Deep X-Rays.	Deep X-Rays and Surgery.	Radium and Superficial X-Rays.	Superficial X-Rays alone.
Rodent Ulcers	79	5	—	74	63	2	2	—	3	—	—	3
Carcinoma of Skin	63	13	3	47	33	5	—	2	3	1	2	1
,, Lip	87	18	1	68	59	4	1	3	—	1	—	—
,, Tongue	51	15	1	35	15	13	—	3	2	2	—	—
,, Floor of Mouth ...	25	4	1	20	8	9	—	—	3	—	—	—
,, Alveolus	11	3	—	8	1	6	—	1	—	—	—	—
,, Cheek	6	1	—	5	4	1	—	—	—	—	—	—
,, Palate	7	—	—	7	4	2	—	—	—	1	—	—
,, Fauces	9	2	1	6	3	2	—	—	1	—	—	—
,, Tonsil	18	4	—	14	—	14	—	—	—	—	—	—
,, Larynx	29	7	—	22	2	20	—	—	—	—	—	—
,, Pharynx	2	—	—	2	—	2	—	—	—	—	—	—
,, Naso-Pharynx ...	1	—	—	1	—	1	—	—	—	—	—	—
,, Jaw	2	1	—	1	—	1	—	—	—	—	—	—
,, Ear	1	1	—	—	—	—	—	—	—	—	—	—
,, Maxillary Antrum...	4	2	—	2	—	2	—	—	—	—	—	—
,, Ethmoid cells ...	1	—	—	1	—	1	—	—	—	—	—	—
,, Thyroid	1	—	—	1	—	—	—	—	1	—	—	—
,, Branchial ...	1	—	—	1	—	1	—	—	—	—	—	—
,, Parotid Gland ...	4	3	—	1	—	1	—	—	—	—	—	—
,, Pr. Glands Neck ...	6	3	—	3	—	3	—	—	—	—	—	—
,, Breast	58	14	—	44	3	33	3	—	1	4	—	—
,, Mediastinum ...	2	1	—	1	—	1	—	—	—	—	—	—
,, Oesophagus ...	7	3	1	3	—	2	1	—	—	—	—	—
,, Bronchus ...	3	1	—	2	—	2	—	—	—	—	—	—
,, Cervix	30	2	—	28	12	9	—	—	7	—	—	—
,, Body of Uterus ...	2	—	—	2	1	1	—	—	—	—	—	—
,, Vagina	1	—	—	1	1	—	—	—	—	—	—	—
,, Vulva	2	2	—	—	—	—	—	—	—	—	—	—
,, Ovary	2	1	—	1	—	1	—	—	—	—	—	—
,, Cystic Adenoma of Ovary ...	1	—	—	1	—	1	—	—	—	—	—	—
,, Chorion Epith. ...	1	—	—	1	—	1	—	—	—	—	—	—
,, Penis	4	2	—	2	1	—	1	—	—	—	—	—
,, Testes	2	—	—	2	—	2	—	—	—	—	—	—
,, Prostate	3	2	—	1	—	1	—	—	—	—	—	—
,, Bladder	2	1	—	1	—	1	—	—	—	—	—	—
,, Hypernephroma ...	1	—	—	1	—	1	—	—	—	—	—	—
,, Urethra	2	—	—	2	1	1	—	—	—	—	—	—
,, Colon	2	2	—	—	—	—	—	—	—	—	—	—
,, Rectum	14	1	—	13	1	—	10	2	—	—	—	—
,, Anus	2	2	—	—	—	—	—	—	—	—	—	—
,, Pancreas... ...	1	1	—	—	—	—	—	—	—	—	—	—
Sarcoma	10	1	—	9	—	8	1	—	—	—	—	—
Endothelioma	1	—	—	1	—	1	—	—	—	—	—	—
Meningioma	1	—	—	1	—	1	—	—	—	—	—	—
Orbital Tumour	1	—	1	—	—	—	—	—	—	—	—	—
Chloroma	1	—	—	1	—	1	—	—	—	—	—	—
Haemangioma...	1	1	—	—	—	—	—	—	—	—	—	—
Hodgkin's Disease	5	1	—	4	—	4	—	—	—	—	—	—
Malignant Papilloma	1	—	1	—	—	—	—	—	—	—	—	—
Total	571	120	10	441	213	182	19	11	21	9	2	4

RECORD OF CASES TREATED IN PAST FOUR YEARS.

Cancer of Lip.

Stage I.

Alive in:—				
				March.
1934	'35	'36	'37	'38
9	8	7	6	3
	12	11	10	5
		35	24	22
			38	37

Stage II.

Alive in:—				
				March.
1934	'35	'36	'37	'38
2	1	1	1	1
	5	3	3	1
		8	7	4
			23	20

Stage III.

Alive in:—				
				March.
1934	'35	'36	'37	'38
4	1	1	1	0
	16	9	8	3
		16	13	4
			7	3

Cancer of Tongue.

Stage I.

Alive in:—				
				March.
1934	'35	'36	'37	'38
10	7	5	3	2
	20	10	10	4
		20	14	10
			15	11

Stage II.

Alive in:—				
				March.
1934	'35	'36	'37	'38
4	2	2	1	0
	8	2	0	0
		9	8	6
			10	10

Stage III.

Alive in:—				
				March.
1934	'35	'36	'37	'38
3	0	0	0	0
	11	1	1	0
		7	3	3
			10	5

Cancer of Cheek.

Stage I.

Alive in:—				
				March.
1934	'35	'36	'37	'38
1	1	1	1	1
	5	4	3	2
		3	2	2
			2	2

Stage II.

Alive in:—				
				March.
1934	'35	'36	'37	'38
1	0	0	0	0
	0	–	–	–
		2	2	2
			1	0

Stage III.

Alive in:—				
				March.
1934	'35	'36	'37	'38
2	0	0	0	0
	1	0	0	0
		0	–	–
			2	1

Cancer of Alveolus.

Stage I.

Alive in:—										
				March.						March.
1934	'35	'36	'37	'38	1934	'35	'36	'37	'38	
0	–	–	–	–	0	–	–	–	–	
	3	1	1	1		0	–	–	–	
		1	1	0			1	1	0	
			2	2				4	2	

Stage II.

Stage III.

Alive in:—				
				March.
1934	'35	'36	'37	'38
2	0	0	0	0
	4	0	0	0
		3	0	0
			2	1

Cancer of Palate.

Stage I.

Alive in:—										
				March.						March.
1934	'35	'36	'37	'38	1934	'35	'36	'37	'38	
1	1	1	1	1	0	–	–	–	–	
	3	1	0	0		0	–	–	–	
		3	2	0			4	3	0	
			5	4				1	1	

Stage II.

Stage III.

Alive in:—				
				March.
1934	'35	'36	'37	'38
1	0	0	0	0
	2	0	0	0
		0	–	–
			1	0

Cancer of Floor of Mouth.

Stage I.

Alive in:—										
				March.						March.
1934	'35	'36	'37	'38	1934	'35	'36	'37	'38	
3	2	2	2	2	0	–	–	–	–	
	2	2	2	2		1	1	0	0	
		7	7	5			0	–	–	
			11	8				3	2	

Stage II.

Stage III.

Alive in:—				
				March.
1934	'35	'36	'37	'38
0	–	–	–	–
	5	1	0	0
		3	3	1
			6	1

Cancer of Fauces.

Stage I.

Alive in:—										
				March.						March.
1934	'35	'36	'37	'38	1934	'35	'36	'37	'38	
0	–	–	–	–	0	–	–	–	–	
	2	0	0	0		1	1	0	0	
		1	1	1			0	–	–	
			3	3				2	2	

Stage II.

Stage III.

Alive in:—				
				March.
1934	'35	'36	'37	'38
0	–	–	–	–
	5	1	0	0
		3	3	0
			1	0

Cancer of Tonsil.

Stage I.

Alive in:—				
				March.
1934	'35	'36	'37	'38
0	–	–	–	–
	4	3	3	0
		2	2	1
			2	2

Stage II.

Alive in:—				
				March.
1934	'35	'36	'37	'38
0	–	–	–	–
	1	1	1	1
		2	2	0
			1	1

Stage III.

Alive in:—				
				March.
1934	'35	'36	'37	'38
4	2	0	0	0
	9	3	2	0
		8	3	3
			11	4

Cancer of Larynx.

Extrinsic.

Alive in:—				
				March.
1934	'35	'36	'37	'38
4	0	0	0	0
	10	0	0	0
		12	1	1
			13	5

Intrinsic.

Alive in:—				
				March.
1934	'35	'36	'37	'38
0	–	–	–	–
	0	–	–	–
		1	1	0
			1	1

Post Cricoid.

Alive in:—				
				March.
1934	'35	'36	'37	'38
2	0	0	0	0
	4	0	0	0
		3	0	0
			8	0

Cancer of Breast.

Stage I.

Alive in:—				
				March.
1934	'35	'36	'37	'38
2	0	0	0	0
	6	3	3	3
		6	6	6
			7	5

Stages II and III.

Alive in:—				
				March.
1934	'35	'36	'37	'38
2	0	0	0	0
	10	4	4	4
		21	4	4
			19	16

Post operative recurrence. Palliative treatment only.

Alive in:—

1934	'35	'36	'37	March. '38
3	1	1	1	1
	5	2	2	2
		14	5	5
			11	9

Post Operative. Prophylactic treatment only.

Alive in:—

1934	'35	'36	'37	March. '38
3	0	0	0	0
	5	2	0	0
		1	0	0
			7	7

Cancer of Skin.

Stage I.

Alive in:—

1934	'35	'36	'37	March. '38
15	13	13	13	5
	38	32	31	6
		42	39	28
			41	32

Stage II.

Alive in:—

1934	'35	'36	'37	March. '38
0	–	–	–	–
	1	1	1	1
		2	2	2
			4	4

Stage III.

Alive in:—

1934	'35	'36	'37	March. '38
0	–	–	–	–
	1	1	1	1
		2	2	1
			2	2

Rodent Ulcers.

Alive in:—

1934	'35	'36	'37	March. '38
49	31	23	17	13
	38	32	31	19
		57	48	37
			74	56

Cancer of Cervix Uteri.

Stage I.

Alive in:—

1934	'35	'36	'37	March. '38
0	–	–	–	–
	0	–	–	–
		2	2	2
			11	10

Stage II.

Alive in:—

1934	'35	'36	'37	March. '38
1	1	1	1	0
	5	3	2	1
		4	3	2
			4	4

Stage III.

Alive in:—

1934	'35	'36	'37	March. '38
0	–	–	–	–
	5	0	0	0
		16	13	3
			13	6

Cancer Body of Uterus.

Alive in:—

1934	'35	'36	'37	March. '38
4	4	4	4	2
	8	3	3	3
		7	2	2
			2	0

REPORT RECEIVED FROM OLIVER CHANCE, M.B., B.CH., D.M.R.E.,

Richmond, Sir P. Dun's, Dr. Steevens', Rotunda, and Coombe Hospitals.

During 1937 most of the cases requiring radiation seen in the above hospitals were referred to St. Anne's Hospital for treatment. The bulk of the cases included below were either private patients or else suffering from such conditions as Rodent Ulcers, for which they could be treated as out-patients.

Malignant Cases.

Treated by—

Surgery alone	3
Radium alone	39
Deep X-ray alone	23
Radium and Surgery	5
Deep X-ray and Surgery	9
Radium and X-rays	5
Radium, Surgery, and X-rays	1
Total, ...	85

Rodent Ulcers, 26.

Treated with X-rays, 2. Treated with Radium, 24. Well, 20. Unimproved, 2. Still under treatment, 1. Untraced, 3.

Carcinoma of Skin, 5.

Treated by Surgery, 1. Treated with X-rays, 2. Treated with Radium, 2. Well, 1. Still under treatment, 1. Dead, 3.

	No. of Cases.	Symptom free.	Unimpr.	Still under treatment.	Pr. well glands involved.	Dead.
Carcinoma Lip, 5.						
Group I ...	2	2	–	–	–	–
Group II ...	2	2	–	–	–	–
Group III ...	1	1	–	–	–	–
Carcinoma Tongue, 3.						
Group II ...	3	2	–	–	1	–
Carcinoma Cheek, 2.						
Group I ...	2	2	–	–	–	–
Carcinoma Palate, 2.						
Group I ...	2	1	–	–	–	1
Carcinoma Floor of Mouth, 2.						
Group I ...	2	2	–	–	–	–

Carcinoma Cervix Uteri, 5.

Operable, 3. Symptom free, 3.

Inoperable, 2. Symptom free, 1. Improved, still active, 1.

Carcinoma Body of Uterus, 2.

Treated with X-rays and Surgery, 1. Treated with X-rays alone, 1. Well, 1. Dead, 1.

Carcinoma Ovary, 1.

Dead, 1.

Carcinoma Breast, 12.

	No.	Free.	Unimpr.	Improved.	Dead.
Prophylactic X-rays ...	5	3	1	–	1
Primary irradiation ...	1	–	1	–	–
Post-operative recurrence	4	–	–	3	1

2 patients were treated by operation alone.

Carcinoma Larynx (Intrinsic), 1.

Treated with Radium, 1. Well, 1.

Carcinoma Larynx (Extrinsic), 4.

Treated by X-rays, 4. Well, 2. Dead, 1. Still under treatment, 1.

Carcinoma Larynx (Post-cricoid), 2.

Treated by X-rays, 2. Well, 1. Dead, 1.

Carcinoma Thyroid, 1.

Treated with X-rays, 1. Improved, 1.

Carcinoma Parotid, 1.

Treated with Radium, 1. Unimproved, 1.

Branchial Carcinoma, 1.

Treated with X-rays, 1. Unimproved, 1.

Carcinoma rectum, 2.

Treated with X-rays, 2. Improved, 1. Unimproved, 1.

Sarcoma, 3.

Treated, 3. Improved, 1. Untraced, 1. Dead, 1.

Seminoma, 1.

Treated by X-rays and Surgery, 1. Well, 1.

Carcinoma Oesophagus, 1.

Treated with X-rays, 1. Dead, 1.

Unclassified, 3.

Non-Malignant Cases.

Toxic Goitre, 5.

Well, 3. Improved, 1. Still under treatment, 1.

Adenoma Prostate, 2.
Treated with X-rays, 2. Well, 1. Unimproved, 1.

Warts, 1.
Well, 1.

Naevi, 7.
Well, 3. Dead, 1. Still under treatment, 3.

Fibrosis Uteri, 1.
Well, 1.

Osteo Arthritis, 1.
Untraced, 1.

Syringo-myelia, 1.
Improved, 1.

REPORT RECEIVED FROM DR. OSWALD J. MURPHY, ST. VINCENT'S HOSPITAL.

During the year under review there has been a small decrease in the number of malignant cases treated. This is due to lack of accommodation in the hospital.

It is disappointing to have to record that on an average the cases seen were in a more advanced stage of disease than any other year since I furnished reports to the Royal Dublin Society.

This is a serious matter, and a matter of vital importance, needing immediate investigation and correction. It is an existing state of affairs which should be brought to the notice of the Minister for Public Health. The conditions I refer to in the series of cases treated by me during the last year are cancer of the tongue, tonsil, lip, and skin surfaces.

It is essential that the public be educated and their attention focused on such conditions as warty growths and ulcers persisting in the mouth, on the lip, on skin surfaces, lumps in the breast, etc., etc.

In my opinion health talks on the wireless, or in the press, should be given regularly, and emphasis laid on such conditions as I have mentioned above.

Malignant Cases Treated during 1937.

Number treated by Surgery alone ...	...	1
Number treated by Surgery and Radium	...	6
Number treated by Radium alone ...	...	96
Number treated by Radium and X-Ray	...	0
Total,	...	103

Malignant Cases.	Seen.	Treated.
Carcinoma of the Ear ...	5	3
„ of the Lip ...	7	6
„ of the Cheek ...	5	4
„ of the Parotid ...	1	1
„ of the Tongue ...	11	8
„ of Floor of Mouth	3	3
„ of Palate ...	2	2
„ of Antrum ...	2	1
„ of Tonsil ...	1	1
„ of Pharynx ...	2	–
„ of Oesophagus ...	1	–
„ of Breast ...	1	1
„ of Breast (Secondaries) ...	5	3
„ of Penis ...	1	1
„ of Anus ...	2	1
„ of Uterine Cervix ...	9	9
„ of Uterine Body ...	6	5
„ of Skin Surfaces	28	26
Rodent Ulcers	27	27
Sarcoma of Cheek	1	1
	120	103

Non-Malignant Cases.	Seen.	Treated.
Exophthalmic Goitre ...	5	3
Hodgkin's Disease ...	8	6
T.B. Cervical Glands ...	6	5
T.B. Peritonitis ...	9	9
Uterine Hæmorrhages ...	4	3
Augiomata	16	16
Lupus Vulgaris ...	1	1
Lupus Erythematosus ...	2	2
Keloids	2	2
Dupytron Contraction ...	5	4
Warts	29	29
Hypertrichosis ...	1	1
	88	81

Results of Treatment.

Malignant Cases.

Carcinoma of the Ear, 3.

	No. treated.	Apparently well.	Improved.	Unimproved.	Untraced.	Died.
No glands ...	2	1	–	–	1	–
Glands ...	1	–	1	–	–	–

Carcinoma of the Lip, 6.

	No. treated.	Apparently well.	Improved.	Unimproved.	Untraced.	Died.
No glands ...	5	3	2	–	–	–
Glands ...	1	–	1	–	–	–

Carcinoma of the Cheek, 4.

	No. treated.	Apparently well.	Improved.	Unimproved.	Untraced.	Died.
No glands ...	3	1	1	–	1	–
Glands ...	1	–	1	–	–	–

Carcinoma of the Tongue, 8.

Anterior Third of Tongue, 2.

	No. treated.	Apparently well.	Improved.	Unimproved.	Untraced.	Died.
No glands ...	1	1	–	–	–	–
Glands ...	1	–	1	–	–	–

Middle Third, 4.

	No. treated.	Apparently well.	Improved.	Unimproved.	Untraced.	Died.
No glands ...	1	1	–	–	–	–
Glands ...	3	–	2	–	1	–

Posterior Third, 2.

	No. treated.	Apparently well.	Improved.	Unimproved.	Untraced.	Died.
No glands ...	1	–	1	–	–	–
Glands ...	1	–	1	–	–	–

Carcinoma of Floor of Mouth, 3.

	No. treated.	Apparently well.	Improved.	Unimproved.	Untraced.	Died.
No glands ...	1	1	–	–	–	–
Glands ...	2	–	2	–	–	–

Carcinoma of Uterine Cervix, 9.

	No. treated.	Apparently well.	Improved.	Unimproved.	Untraced.	Died.
Group I ...	4	3	1	–	–	–
Group II ...	1	1	–	–	–	–
Group III ...	4	–	2	–	–	2

Carcinoma of Uterine Body, 5.

	No. treated.	Apparently well.	Improved.	Unimproved.	Untraced.	Died.
Group I ...	3	1	1	–	1	–
Group II ...	1	–	1	–	–	–
Group III ...	1	–	–	–	–	1

Carcinoma of Skin Surface, 26.

	No. treated.	Apparently well.	Improved.	Unimproved.	Untraced.	Died.
No glands ...	25	15	6	1	3	–
Glands ...	1	–	1	–	–	–

Rodent Ulcers, 27.

No. treated.	Apparently well.	Improved.	Unimproved.	Untraced.	Died.
27	22	2	–	3	–

Non-Malignant Cases.

There is nothing of note to report regarding these non-malignant conditions.

SUMMARY OF SOME OF THE MORE IMPORTANT GROUPS OF MALIGNANT CASES TREATED DURING THE SEVEN-YEAR PERIOD, 1930–1936.

Carcinoma of the Ear.

Year of Treatment.	No. Treated	Alive after 1	2	3	4	5	6	7 years.
1930	3 ...	2	2	1	1	1	1	1
1931	0 ...	0	.	.	.	.	.	
1932	0 ...	0	.	.	.	.	.	.
1933	2 ...	2	1	1	1			
1934	4 ...	3	3	3				
1935	4 ...	3	2					
1936	5 ...	5						

Carcinoma of Cheek.

Year of Treatment.	No. Treated	Alive after 1	2	3	4 years.
1933	4 ...	4	3	3	2
1934	6 ...	5	5	4	
1935	4 ...	3	3		
1936	3 ...	3			

Carcinoma of the Tongue.

Year of Treatment.	No. Treated	Alive after 1	2	3	4	5	6	7 years.
1930	5 ...	3	2	1	1	0	0	0
1931	4 ...	2	1	1	1	0	0	
1932	8 ...	4	3	3	2	1		
1933	3 ...	2	1	1	0			
1934	5 ...	2	2	1				
1935	9 ...	5	2					
1936	10 ...	6						

Carcinoma of the Lip.

Year of Treatment.	No. Treated	Alive after 1	2	3	4	5	6	7 years.
1930	5 ...	3	2	2	1	1	1	1
1931	3 ...	2	2	1	1	1	0	
1932	7 ...	5	4	4	3	2		
1933	6 ...	5	4	4	2			
1934	7 ...	5	5	3				
1935	8 ...	6	2					
1936	8 ...	7						

Carcinoma of the Palate.

Year of Treatment.	No. Treated	Alive after 1	2	3	4	5	6	7 years.
1930	2 ...	1	1	1	1	0	0	0
1931	2 ...	1	1	1	1	0	0	
1932	4 ...	3	2	0	0	0		
1933	2 ...	2	2	2	2			
1934	1 ...	1	1	0				
1935	2 ...	1	1					
1936	1 ...	1						

Carcinoma of the Tonsil.

Year of Treatment.	No. Treated	Alive after 1	2	3	4	5	6	7 years.
1930	1 ...	1	0	0	0	0	0	0
1931	2 ...	1	1	0	0	0	0	
1932	3 ...	2	2	1	0	0		
1933	2 ...	1	1	1	1			
1934	5 ...	3	2	1				
1935	3 ...	2	1					
1936	1 ...	1						

Carcinoma of the Larynx and Pharynx.

Year of Treatment.	No. Treated	Alive after 1	2	3	4	5	6	7 years.
1930	3 ...	1	0	0	0	0	0	0
1931	4 ...	1	0	0	0	0	0	
1932	5 ...	1	1	1	0	0		
1933	1 ...	1	0	0	0			
1934	2 ...	2	0	0				
1935	3 ...	2	1					
1936	1 ...	0						

Carcinoma of the Breast (Primary).

Year of Treatment.	No. Treated	Alive after 1	2	3	4	5	6	7 years.
1930	5 ...	2	1	0	0	0	0	0
1931	4 ...	2	1	1	1	0	0	
1932	0 ...	–	–	–	–	–		
1933	2 ...	1	1	0	0			
1934	2 ...	1	1	1				
1935	5 ...	3	1					
1936	4 ...	3						

Carcinoma of the Breast (Secondaries).

Year of Treatment.	No. Treated	Alive after 1	2	3	4	5	6	7 years.
1930	6 ...	3	0	0	0	0	0	0
1931	6 ...	2	1	0	0	0	0	
1932	0 ...	–	–	–	–	–		
1933	11 ...	2	1	1	1			
1934	14 ...	4	1	0				
1935	7 ...	3	1					
1936	8 ...	5						

Carcinoma of the Cervix Uteri.

Year of Treatment.	No. Treated	Alive after 1	2	3	4	5	6	7 years.
1930	4 ...	2	2	1	1	1	1	1
1931	3 ...	1	1	1	1	1	0	
1932	8 ...	5	4	4	3	1		
1933	3 ...	2	2	1	1			
1934	3 ...	3	2	2				
1935	5 ...	4	2					
1936	7 ...	5						

All untraced cases in this series are presumed to be dead.

No. 4.

ON A RECENT BOG-FLOW IN THE COUNTY WICKLOW.

By G. F. MITCHELL.

Plate 1.

[Read April 26. Published separately July 6, 1938.]

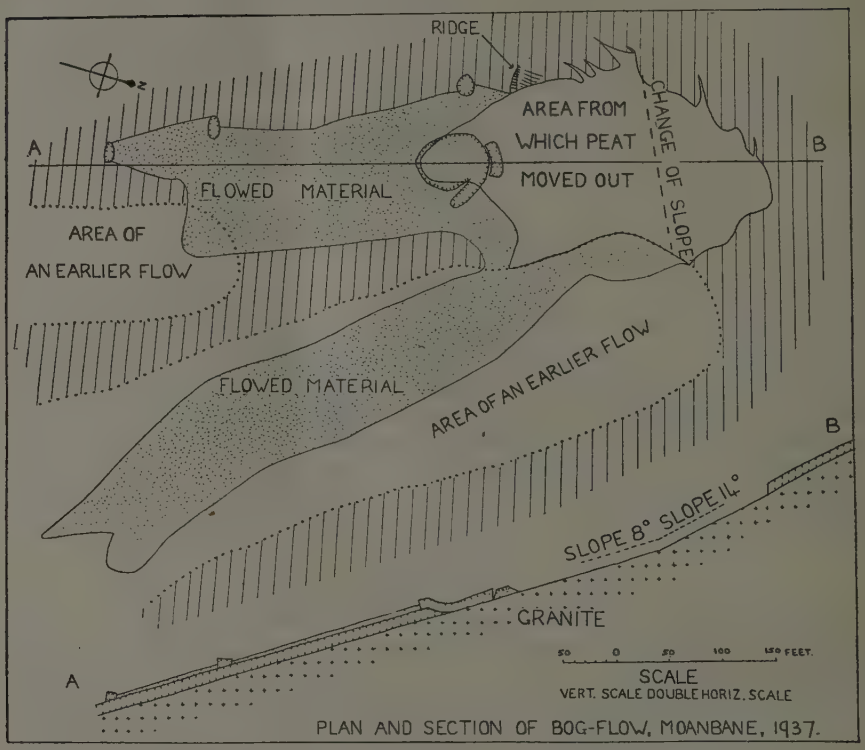
Preliminary.

When walking in the Wicklow Mountains on June 6th, 1937, Professor L. B. Smyth discovered the flow which is described in the paper. Shortly afterwards I accompanied him to the site, and I have since visited it on several occasions both with him and others, who included Professor Hugo Osvald, of Uppsala, and Mr. A. Farrington. Suggestions contributed by these visitors during discussions on the site are incorporated in the paper. To all I am indebted, but especially to Professor Smyth and to Mr. D. Lonergan, who enabled me to see the site from the air and also took many aerial photographs.

Description.

From the western slopes of Mullaghcleevaun (2,788 ft.: 849 m.) a spur runs westwards for about two miles, and then rises to 2,313 ft. (705 m.), to form the summit of Moanbane. Here the spur turns south-west, and about one mile from the top of Moanbane there is a second summit at 2,296 ft. (700 m.). The spur is made of granite, and has the rounded profile characteristic of the Wicklow hills; but at about 1,800 ft. (548 m.), and to the south-east of the lower summit, the convex flank of the mountain is interrupted by a subsidiary spur, which runs in a south-easterly direction for a short distance. To the east of this spur the surface water drains along the Glasnadade Brook towards Glenbride in the south-east, to the west the drainage runs south to the King's river valley. The bog-flow took place at the point where the spur runs out at a shallower angle from the convex slope, about 600 yds. south-east of the 2,296 ft. summit. The slope of the mountain immediately above, and to the east and west of the spur, is 14°, and the slope on the flatter top of the latter is 8°.

The side of the mountain and the spur are uniformly covered by a mantle of peat, which is about six feet (2 m.) deep, and rests directly on the granite below. The surface vegetation is of a wet type, the principal plants being *Scirpus caespitosus, Eriophorum vaginatum* and *polystachion, Sphagnum spp., Empetrum nigrum, Vaccinium myrtillus,* and *Calluna.* Plants of *Calluna* were rather scattered and nowhere big. The ground was noticeably wet, but firm under foot.



From an area, roughly oval in shape, measuring 100 yds. along the slope and 60 yds. across, the bulk of the peat had moved forward, leaving patches of granite exposed in the floor of the area. The line along which the change of slope from convex mountain side to the gently-inclined top of the spur ran in an east-west direction through the centre of this area. The flowed material lay in two branches—one almost directly south of the burst, the other slightly to the south-east (Fig. 1, Pl. I). It was obvious that the flow had taken place some little time previously. Inquiries in the village of Glenbride produced the information that the Glasnadade Brook (which would have received any water released by the burst) had not been swollen abnormally nor charged with peaty material at any time, but that when the shepherds had gone up the mountain in the first fortnight in March to bring down the sheep, as they expected snow, they had discovered it for the first time. The mountain is, of course, not often visited, but opinion agreed that the flow must have taken place in the first quarter of 1937.

Examination of the peat face at a typical profile in the upper margin of the flow revealed the following stratification:—

0–30 ins. 0–75 cms.	Brown slightly humified peat, with many fibres and roots of *Eriophorum*, twigs of *Calluna*.
30–50 ins. 75–127 cms.	Brown well humified peat, as above.
50–74 ins. 127–188 cms.	As above, but more firm.
74–78 ins. 188–198 cms.	Black-brown amorphous peat.
at 78 ins. 198 cms.	Granite.

Due to the firmness of the lower layers of the peat, no great volume of water was released by the flow, nor had the lower layers flowed out from beneath the upper layers above the actual area of the burst. Large cracks were to be seen round the upper margin, but they did not extend to any distance from it, nor had they any regular arrangement. There was no welling-up of softer peat between the cracks.

In marked contrast to the vertical upper margin was that part of the margin over which the southern branch of the flowed material had moved out. From the boundary of the undisturbed bog surface downhill from the burst, the margin sloped gently inwards towards the centre of the burst, and up this gentle slope the flowed material had moved to rise on to the bog surface. Immediately to the west of the margin of the exit an interesting feature was seen. A slice of the crust had been both thrust upwards at a shallow angle and tilted forwards, so that the appearance of a ridge was produced (Fig. 2, Pl. I), and the end of this slice nearest to the exit had been dragged further forward and rotated slightly, so that it rested on the bog surface, but was connected *via* the slice with undisturbed bog further to the west.

The southern branch of the flowed material was composed to a large extent of sods of considerable size, which showed no signs of having been rolled over (Fig. 2, Pl. I). Rather they gave the impression of having mounted upon the bog surface and then glided gently forward, the more decomposed lower layers acting as a lubricant. It was noticed that the sods that had travelled the greatest distance were thinner than their fellows that had not moved so far. The largest sod seen, a circular raft about 20 yds. in diameter, had failed to mount completely up the slope, and lay stranded with its downhill margin on the bog surface, but the bulk of the sod on the granite. It had thus assumed the shape of a saucer, and a small pool of water was lodged in it (Fig. 2, Pl. I).

The material in the south-east branch of the flow was of a different nature; no large sods were seen, and it consisted of the smaller debris that had rolled along, turning over and over in the course of its movement. The rate of

progress had, no doubt, been slow, and here again there was no evidence of any volume of water having been released by the burst. The track it had followed lay in the floor of a heather-clad depression in the bog surface, and the head of this depression abutted on the area from which the flow had moved out. The burst, spreading laterally, had invaded the depression, and so made an easier exit available for the smaller debris.

Attention was directed to this depression and to a second one, also covered with heather, which lay between the two arms of the flow. They were comparable in size to the hollow produced by the present flow, and when it was discovered that each terminated downhill in an area of irregular peat-tussocks, it became difficult to resist the supposition that these depressions, now clothed in vegetation, were in fact the sites of former bog flows. A search was made at the base of the tussocks to see if any evidence of moved sods resting on a former peat surface could be discovered. At one point the following section was found:—

0–12 ins. 0–30 cms.	Rather dry well humified dark-brown peat.
12–14 ins. 30–36 cms.	Well preserved remains of *Eriophorum* and *Calluna*.
14–29 ins. 36–74 cms.	Slightly humified light-brown peat.
29–32 ins. 74–81 cms.	Well humified dark-brown peat.
at 32 ins. 81 cms.	Granite sand.

It is probable that the layer with well preserved remains of *Eriophorum* and *Calluna* represents the original bog surface and that the well humified peat resting on it is moved material.

On the supposition that these depressions were the remains of earlier flows, the upper parts or the areas where the initial burst may have taken place were again examined, and it was discovered that while the head of the more eastern of these two flows lay across the change in slope, as did the head of the 1937 flow, the whole extent of the second of the earlier flows lay on the flattened top of the spur, and no change of gradient was apparent in its floor.

Discussion.

With regard to the recent flow on this mountain, it seems likely that the change of slope from 14° on the mountain flank to 8° on the top of the spur must have stood in some causal relation to the burst. The thick layer of peat on the upper slope may have tended to slide slowly downhill, and as this movement was checked by the flatter slope of the spur, the peat may have welled up into a ridge, a cross-section of which would have suggested an incipient

overfold. A tear at the base of the ridge caused by the forward shearing movement would allow the base to slide forward, and up on to the intact surface of the peat in front. The remnants of such a ridge discovered at the western margin of the flow, and described above, lend support to such a picture.

The energy accumulated during the welling-up of the ridge was probably only sufficient to carry the large sods up the short slope to the bog surface. After travelling sedately down the slope for a short distance, they were gradually brought to a standstill as friction between the bog surface and the fibrous upper layers of the sods increased, due to the wearing away of the softer lower layers. The largest of the detached sods had not sufficient energy to rise in its entirety on to the surface, and remains stranded across the margin of the flow, indicating clearly the route its comrades followed.

As the burst spread laterally, it broke into the north-east corner of an earlier flow, thus finding an exit where it was not necessary for the flowing debris to surmount the sloping margin, for the peat had already been removed from this area. This easier route was followed by the smaller debris rolling over and over as it moved down the depression in the bog surface, but it was also soon brought to a standstill, the degree of slope not providing sufficient momentum for a lengthy flow.

The most striking difference between this flow and others that have been recorded in recent years (1, 2, 3) is that here the underlayers of the bog did not contain large quantities of water, whose release in the other cases caused the more violent and catastrophic features of those flows. The size of the actual burst on Moanbane does not compare unfavourably with the other examples, but here only the peat, semi-solid throughout its entire thickness, in the immediate vicinity of the burst was released, whereas elsewhere (1, 2, 3) the underlayers were charged with water, and drained out, not only from the neighbourhood of the burst itself, but also from under the more solid crust, for considerable distances. By this means disturbance of the surface was greatly increased; for the first drainage surge broke the upper layers into floes, which were carried off by the flood, but further away, where the draining was less violent, the upper layers slumped downwards and forwards, their surface seamed by large tears, but were not carried bodily forward on the flood. Here, where the lower layers were solid, disturbance was slight, and the track of the debris short; elsewhere large quantities of water, charged with debris, were released, to travel considerable distances, causing much damage, and in one case loss of human lives (1).

The Kerry burst of 1896 (1) took place in a lowland bog, which had been injudiciously cut into by the peasants. The present burst affected a mountain bog, and no peat cuttings had been made in the vicinity of the flow, nor was the uniform peat-cover of the area interrupted anywhere by escarpments, as in the Clare flow of 1934 (3). A change of gradient was also noted at the site of the flow in Mayo in 1931 (2), which occurred in a mountain bog, the slope above the flow being 3° and the slope below 4°. Here, by contrast to the present flow,

the gradient steepens below the burst, but the change of gradient may have caused some strain in the upper layers of the peat.

With regard to the two depressions lying in the immediate vicinity of the burst, which terminate downhill in tangled areas of peat tussocks, in view both of their general shape and the section discovered at a tussock base in one of them, it seems difficult to resist the conclusion that these are indeed the remains of earlier flows, now overgrown by vegetation. The head of the more eastern of the flows occurs at about the same level as the recent one, and the change of slope may also be invoked as a causative agent in this case. The second of the earlier flows, however, lies on the uniformly sloping top of the spur; no change of slope is involved here, and perhaps a *caveat* should be entered against too easy acceptance of the change of slope being the cause in the other two instances.

The discovery of these three flows lying so closely together stimulated an inspection of the hillsides in the immediate vicinity to see if yet others could be discovered, but no convincing evidence was forthcoming. Of course the more striking features of these bursts must disappear comparatively rapidly under the influence of the weather and of renewed peat growth, and the presence of even these three flows is sufficient proof that these bursts must be more frequent than has been generally recognised.

Support for this view occurs in a note, incorporated in 1, p. 497, describing a flow which took place in a mountain bog, Dungiven Bog, Co. Derry, in 1895, in which it is stated: "There is evidence of similar slides having taken place in the district."

In all cases where bursts in mountain bogs have been investigated there are indications that growth had rendered the bog unstable, and that the burst acted as a safety-valve to restore equilibrium. Such bursts may occupy a definite position in the cycle of development of bogs resting on sloping surfaces.

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FIG. 1.—General view of the mountain-flank below the 2,296 ft. (700 m.) summit, and of the bog-flow, from the south.

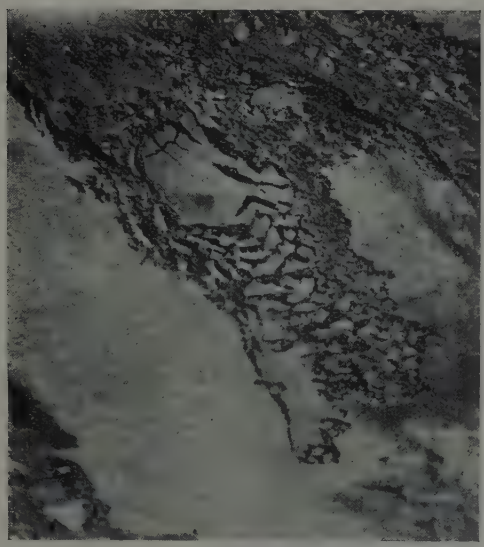

FIG. 2.—View of southern branch, showing also marginal ridge and border of an earlier flow, from the south-west.

No. 5.

SUBAQUEOUS TRANSPIRATION.

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[Read March 22. Published separately July 13, 1938.]

Experiments made in 1897 (1) on cut leafy branches of *Chrysanthemum sinense, C. lacustre, Myrtus communis, Eucalyptus globulus, Escallionia macrantha,* and *Cheiranthus cheiri,* enclosed in saturated spaces and even completely submerged in water, were interpreted in the sense that leaf-cells frequently are able to abstract water from the conducting tracts and to secrete it into the intercellular spaces of the leaf. This abstraction of water by evaporation from the leaves was indicated by a rise of eosin-solution supplied to the cut lower ends of the branches. Before the coloured solution was applied to the cut ends, the experimental branches, supplied freely with water, were kept for one hour in a saturated dark chamber. In this way it was hoped that any reduced pressure within the branch would be equalized before the application of the eosin.

In 1931 Smith, Dustman, and Shull (2) criticised the above conclusion, and reported that when they took precautions to satisfy the water-deficit of the experimental branch, before applying the eosin solution, they failed to observe any significant rise. They consequently concluded that the rise, which I had observed, was attributable to a water-deficit in my experimental branches, and was not due to secretion of water by cells from the foliar tracheae. It may be noted in passing that in several of their own experiments the time allowed for the removal of the water-deficit was no more than one hour.

These discrepant results made it necessary to repeat the early experiments with greater precautions against this water-deficit, by allowing a much longer time for the branches to become glutted with water. A sojourn of 20–24 hours in a saturated space with freshly cut ends submerged in water previous to the application of the eosin was judged to be sufficient to remove all fear that the rise observed could be attributed to a water-deficit.

At first I hesitated to submerge the branches completely during this long preparatory period, lest the cutting off of the air from the leaf-cells might so debilitate them that their secretory powers (if any) might be lost. Accordingly a glass vessel was arranged, lined with moist bibulous paper adhering to its walls, to enclose the experimental branches and their water supply. It was further arranged that without opening the vessel new surfaces could be cut after the period of saturation, and that subsequently the water supply could

be replaced by eosin solution. Experimenting with these precautions on branches of *Chrysanthemum sinense,* in each case I observed a significant rise of eosin in the stem, viz.:

In Branch	A	carrying	16	leaves	a rise	in	one	hour	of	17·5 cm.
„	„	B	„	16	„	„	„	„		17·5 „
„	„	C	„	10	„	„	„	„		12·5 „

As the American experimenters had apparently completely submerged their material I wished to see if the cutting off of free oxygen was responsible for the discrepancy in our observations. With this in view I fixed the experimental branches into the tubulure entering the closed end of a glass bell. The cut end of the branch projected downwards into the supply vessel, while the leaves projected upwards into the bell, which was quite filled with water. During the preparation period, and subsequently after the water supply had been replaced by eosin solution, a continuous stream of minute bubbles was delivered from a rose-shaped electric bubbler in the bottom of the water surrounding the leaves. Again with this arrangement significant rises of the eosin amounting to 6·5–16 cm. in a couple of hours were observed with *Chrysanthemum sinense* in December, of 2 cm. per hour with *Diervilla rosea* in March, of 15 cm. in 24 hours with *Ribes rubrum* in March; while a single leaf of *Tropaeolum majus* was completely injected through a petiole 24 cm. in length in 2 hours in the month of March. Complete injection of a whole branch with its leaves of *Syringa vulgaris* through a length of stem of 35 cm. was also observed in the month of March.

Similar results were obtained when branches of *Syringa vulgaris* were prepared by 24 hours submergence in dilute (1%–1·5%) solutions of potassium carbonate. In these an oxygen supply was secured during daylight hours by photosynthesis. Finally it was found that, even when no special arrangement was made to supply oxygen to the leaves during the preparatory and experimental periods, but if they were simply exposed to daylight, the aeration was sufficient to allow the leaf-cells to function and secured appreciable rises of the eosin solution in the stems of *Chrysanthemum sinense, Syringa vulgaris,* and *Diervilla rosea.* With a leaf of *Tropaeolum lobbianum,* having a petiole 23 cm. long and submerged for 24 hours in ordinary tap-water, the eosin solution rose in three hours through the petiole and filled practically all the tracheal tracts (great and small) of the blade to their ends.

In no experiment from which oxygen had not been excluded by boiling the water surrounding the leaves did the eosin fail to rise 1·5 cm. by the end of the first hour. Normally the rise was from 10 to 25 cm., and often the stems and leaves were generally injected to a height of 30 cm. in 2 hours.

Summary.

Marked rises of eosin solution into the stems, petioles, and leaf-blades of cut branches surrounded by saturated spaces, or completely submerged in water,

may frequently be observed, even when adequate precautions are taken to ensure that there is no water-deficit in the leaves and stems when the eosin is presented to the cut ends of the branches.

Experiments in which considerable volumes of the colourless sap of the leaf-tracheae have been replaced by the coloured solution seem to indicate that water has been abstracted from the tracheae and secreted on the outer cell surfaces.

The contradictory results recorded by Smith, Dustman, and Shull are unexplained.

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